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ELEMENTS

OF

GENERAL ANATOMY,

CONTAINING

AN OUTLINE OF THE ORGANIZATION

OF

THE HUMAN BODY.

BY

R. D. GRAINGER,

LECTURER ON ANATOMY AND PHYSIOLOGY.

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TO

THE STUDENTS IN ANATOMY

OF THE WEBB STREET SCHOOL.

Gentlemen,

In dedicating to you this volume, I feel much pleasure in availing myself of the opportunity it affords me, of publicly expressing the high sense I entertain of the unwearied kindness and support I have experienced from you and from your predecessors.

That you may in after life reap the fruits of a well merited reputation, is the ardent wish of,

Your sincere and obliged Friend,

R. D. GRAINGER.

Theatre of Anatomy and Medicine,
October 1st, 1829.

PREFACE.

The numerous works which have made their appearance in this country relative to the science of anatomy, render it necessary that I should explain my motives for adding to their number by publishing the present Volume.

At the time when I commenced this undertaking, there was no work exclusively devoted to the consideration of the texture of the different parts of the human body. I had frequently noticed amongst my own pupils the inconvenience resulting from such a deficiency, and therefore it occurred to me that I might render them some assistance, by attempting to remove the difficulty they experienced in obtaining an acquaintance with this important branch of anatomical knowledge.

When the materials for the following pages were collected, and when the greater part of the manuscript was finished, a work on the same subject was published by

Dr. Craigie of Edinburgh.* Having proceeded so far in my design, and being under a pledge to complete it, I should not have been justified in foregoing my original intention, the accomplishment of which has been deferred by some unavoidable circumstances.

My object, in this work, has been to convey a concise, and at the same time a comprehensive account of the several substances which form the human body. In endeavouring to effect this purpose I have carefully avoided unnecessary minuteness. This principle, indeed, has perhaps in some instances been carried too far. If such should prove to be the fact, I can only plead in excuse the anxiety I felt to escape the charge of diffuseness.

To the description of the different tissues, some observations on their uses are added, for the purpose of shewing how admirably each structure is adapted to the functions it is destined to fulfil.

In offering these pages to the notice of the public, no claim is made to any great novelty; but it is necessary to state, that I have, by careful and repeated examinations ascertained, as far as the imperfection of our knowledge will allow, the structure of each part that is described. With respect to many of the physiological experiments on living animals to which allusions are made, I confess that I have not repeated them; because, without being influenced by the refined affectation of humanity, which is so fashionable in the present day, I conceive, that when any fact has been clearly and indisputably ascertained, we are not justified in inflicting any farther suffering simply to gratify curiosity.

---

* "Elements of General and Pathological Anatomy." Nov. 1828. As I could only have consulted Dr. Craigie's publication in an imperfect manner, I have not alluded to it in this work.

In availing myself of the great number of facts which have been collected by Bichat, Beclard, and Meckel, I have not neglected other sources of information; particularly those contained in the many valuable works and detached papers that have been published in this country.

Although in arranging this work, I have been principally influenced by the desire of facilitating the studies of my pupils, yet I entertain some hope that it may prove not altogether useless to those who are engaged in the practice of our profession. In the present day, when morbid anatomy is so zealously cultivated, the kind of information included under the term, General Anatomy, is essentially necessary; because it is impossible to appreciate the changes produced by disease in the various parts of the body, without being previously acquainted with their natural and healthy structure.

It may be proper to add, that in the selection of a title, I have been guided by the example of three of the most eminent authorities of modern times,* who have employed the term, *General Anatomy*, to designate that branch of anatomy which has for its object the investigation of the tissues of the body. This expression is, in some respects, objectionable; for in its strict acceptation it comprehends every thing that relates to the science of organization; but custom has sanctioned the use of it in this more limited meaning.

I cannot close these preliminary remarks without acknowledging my obligation to Mr. Cooper, Lecturer on Chemistry, for his kindness in allowing me the use of his excellent microscope; and for his aid in making numerous observations on the composition of the fluid and solid parts of the body. I am also indebted to my colleague, Mr. Pilcher, and to Dr. S. Smith, for the kind assistance I have received from them in the progress of this work through the press.

---

* Bichat, Beclard, Meckel.

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INTRODUCTION.

SECTION I.

OF INORGANIC AND ORGANIC BODIES.

THE material substances which compose the globe of the earth, or which exist upon its surface, are divided into two grand classes: 1. Inorganic, or Mineral bodies. 2. Organic, or Living bodies. These two great divisions are distinguished from each other by certain properties which are determined and invariable.

The composition of inorganic substances is characterized by the following circumstances. 1. Its homogeneousness. 2. The independence of its molecules, each of which is capable of existing independently of the others. 3. The simplicity of its chemical properties. 4. Its peculiarity of constitution, consisting of gaseous, liquid, or solid substances, and never exhibiting a union of fluid and solid parts. 5. Its capability of being decomposed and recomposed.

The composition of living beings exhibits in all the preceding circumstances a striking contrast. 1. The living body is heterogeneous, consisting of dissimilar parts. 2. Its constituent molecules have a mutual and necessary relation to each other, and, consequently, cannot preserve an independent existence. 3. Its elementary substances are numerous, and combined in varying proportions. 4. The fluid and solid parts of which it is composed are intimately combined together and mutually influence each other. 5. It is capable of decomposition, but totally incapable of artificial recomposition.

The form of minerals is not fixed in an invariable manner, nor is there any decided limit to their magnitude. Their external surface is usually angular, and bounded by straight lines. In organized bodies, on the contrary, the form is constant and determined, so that each living being has a proper shape, from which it seldom deviates. This form is rounded, not only on the exterior of the body, but also in its internal and constituent parts.

All material beings are active, that is to say, they execute certain actions which are essential to their preservation, and to those processes by which the great operations of nature are effected; it is, therefore, incorrect to consider mineral bodies as inert.* The properties from which these actions spring, differ in mineral and in organic bodies. In the former they consist of gravitation, repulsion, and chemical affinity; these powers have been called general, because they are exercised in all natural bodies. In the latter, they comprise sensibility and contractility, which are denominated special or vital forces, because they are confined to living beings; the general laws of matter also exert their influence, but in a modified manner. The differences exhibited by these great classes of bodies may be illustrated by contrasting the phenomena they indicate in their origin, their growth, and their termination.

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* Adelon, Physiologie de l'Homme, tom. i. p. 16.

The origin or first formation of minerals results from the operation of external circumstances; thus they are produced by the separation of the particles which compose other minerals, or by the combination of elementary substances, which are united in virtue of their chemical affinities. Organized bodies, on the contrary, owe their origin to an internal operation, which is termed generation; in this process, a substance, called a germ, is attached for a certain period to another similar being, from which it is subsequently detached, and then enjoys a separate and independent existence.*

It has been truly observed by a celebrated writer, that amongst all the characters which distinguish the two great divisions of natural bodies, the most absolute and the most palpable is that which is drawn from the manner of growth and of nourishment.† The mineral grows, or rather increases in bulk, by the accretion and combination of new particles on its external surface. The organized body, on the contrary, is developed and supported, by the introduction of a certain quantity of matter into its interior, where, by a strictly vital action, the foreign substance is converted into a part of the living body. This important process is termed assimilation or nutrition.

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* The primitive attachment of every living body to a similar being, which bears to it the relation of a parent, is probably a rule without an exception. It was, however, supposed by the Ancients, that organized bodies might be formed like minerals, by the operation of the general laws of matter. The curious discoveries that have been made, concerning the existence of the numerous species of infusory animalculæ, have induced several modern physiologists, among whom may be mentioned M. Lamarck, to revive the doctrine of equivocal or spontaneous generation. The extreme minuteness of these animalcules renders it impossible to determine by examination, whether they are formed simply by the combination of the surrounding elementary molecules, or from ova which had been previously deposited in the water used for the experiment. The probabilities are decidedly in favour of the latter opinion. —*Adelon*, l. c. t. i. p. 18.

† Richerand, Elem. of Physiol., edited by Dr. Copland.

The duration of all material bodies is bounded by a certain limit, so that at a definite period, every being ceases to exist; the causes of their dissolution are strikingly different in mineral and organic bodies. The former cease to exist at any time, when they are acted upon by more powerful affinities than those by which their molecules were previously combined; hence it is evident that, as the causes of destruction are external, there can be nothing fixed or determined in the duration of a mineral. The latter are deprived of their existence by various causes, which are distinguished from the preceding, by being internal; these induce such changes in the mechanism of organized bodies, as to unfit it for the performance of those actions, upon which the continuance of life depends. The extinction of the living principle constitutes a phenomenon totally wanting in the mineral kingdom, which is called death.

TABLE

Of the differences between Inorganic and Organic Bodies.

1.—COMPOSITION.

Of Inorganic Bodies.	Of Organic Bodies.
Homogeneous.	Heterogeneous.
Molecules are independent of each other.	Molecules are dependent upon each other.
Simplicity and constancy of chemical properties.	Complexity and variation of chemical properties.
Never presents a union of gaseous, liquid, or solid parts.	Always presents a union of fluid and solid parts.
Capable of being decomposed and recomposed.	Capable of decomposition, but incapable of recomposition.

2.—FORM.

Of Inorganic Bodies.	Variable. Usually angular.	Of Organic Bodies.	Constant. Usually rounded.

3.—ACTIVE PROPERTIES.

Of Inorganic Bodies.	Gravitation. Repulsion. Chemical affinity.	Of Organic Bodies.	Sensibility. Contractility. Gravitation. Repulsion. Chemical affinity.

Section II.

OF VEGETABLES AND ANIMALS.

The numerous beings which are endowed with life and organization, are divided, according to the peculiarities they exhibit, into vegetables and animals. It is difficult to establish a rigorous line of demarcation between these two great classes, because they both participate in many of those properties which are the most essential attributes of organized bodies. Thus, for example, every vegetable and every animal possesses a structure proper to itself, and which is composed of fluid and solid parts intimately combined together; in both classes this structure is produced by generation, developed and supported by nutrition, and destroyed by death. In each instance, also, the ordinary affinities of chemistry and the attraction of gravitation are controlled, and even opposed, by another force, which is called vital; in virtue of which, every living body is enabled to resist the influence of external agents, and thus to preserve its peculiar composition. There is yet one other class of important phenomena, by which the resemblance between vegetable and animal bodies is rendered still more apparent; I allude to those changes which succeed the loss of vitality, and which produce putrid decomposition.

The distinctive marks of plants and animals are, however, numerous and decisive. The former are fixed to the earth, and are incapable of producing perceptible movement: the latter exist upon the surface of the earth, and possess the capability of spontaneous and free motion. Plants, although totally deprived of consciousness, appear to be provided with an obscure kind of sensibility which fits them to receive the impression of nutritive particles. Animals enjoy a higher degree of sensibility, which bestows upon them consciousness, and by which they have the power of perceiving all external impressions, and of determining, by an act of volition, the contraction of their muscles.

Vegetables have a composition which is more complex than that of minerals, but less so than that of animals; they are also distinguished by containing a large quantity of solid matter, and by having carbon for their base; which circumstances explain their remarkable durability and resistance to putrefaction. The animal body, on the contrary, is characterised by the number and volatility of its elementary materials, by the large proportion of its fluids, by having for its base a gaseous and diffusable substance called azote, and, lastly, by the rapidity of its decomposition after death.

The phenomena which are exhibited in the process of nutrition, constitute another and a striking distinction between the two great classes of organized beings. The plant absorbs the particles which are required for its nourishment from the surrounding atmosphere, and especially from the soil in which its roots are implanted.

In every animal, with the exception of a few tribes placed at the bottom of the scale, the alimentary substances are seized by the agency of muscular contraction, and are then introduced into an internal cavity, in which a separation is effected between the nutritious and the useless parts; the former are absorbed and become assimilated with the body, while the latter are discharged under the form of excrement. The process by which the nutritious matter is separated from the common mass of the food, is termed digestion.

DIFFERENCES BETWEEN VEGETABLES AND ANIMALS.

Vegetables	Animals
Are fixed to the earth, have no perceptible motion.	Move upon the surface of the earth.
Have probably an obscure kind of sensibility without consciousness.	Have sensibility accompanied by consciousness.
Are composed of few elements, have much solid matter, and have carbon for their base.	Are composed of many elements, have a large quantity of fluids, and have azote for their base.
Resist decomposition.	Are readily decomposed.
Are nourished by external absorption.	Are nourished by digestion and internal absorption.

Section III.

OF ANIMAL ORGANIZATION.

We learn from the preceding observations that animal bodies are composed of fluid and solid materials, which, being in intimate combination, must necessarily exert a mutual influence upon each other. This combination, which is distinguished by the name of *organization*, is essential to the manifestation of the phenomena of life, and is consequently possessed by all living beings.*

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* In admitting that an organized structure is required for the exercise of

The fluids or humours are contained in the interstices which are formed between the fibres and layers of the organized solids. Their proportion to the latter is so great, that the animal body is always soft in its texture, and rounded in its form. This preponderance is most striking in the lower animals and in the young of all classes; whereas, in the more perfect species, and particularly in old animals, the quantity of solid material is considerably increased. The humours ought to be regarded as the most important elements of organization, because they constitute the medium by which the composition and decomposition of the animal body, are effected. In the former process the nutritive matter is introduced into the system in the form of fluid; in the latter, also, those particles which have for a certain period performed their office in the economy, and which therefore require to be renewed, are discharged from the body in the liquid or gaseous form.

In the lowest tribes of animals the humours appear to be almost, if not entirely, homogeneous, so that they cannot be distinguished from each other by their colour or other physical qualities. In most animals, however, there are four different classes of fluids. 1. Those which are introduced into the body from without, by the absorbing power of the mucous membrane and of the skin. 2. The blood, which is the central mass of the circulating fluids. 3. The fluids which are separated by secretion from the blood. 4. The fluids which

the vital actions, it does not follow that the principle upon which they depend, is the result of organization. From an attentive examination of the properties of organic bodies, I am myself perfectly convinced that organization, and the phenomena which are exhibited in living beings, proceed from the influence of some wonderful principle, which, in its essence, is totally distinct from matter, but which in our present state of existence, is inseparably associated with organized structures.

are absorbed in the substance of the body, and are subsequently returned to the blood.

The solids derived from the fluids, contain the latter and impress upon them those movements which are necessary for secretion and nutrition; there is thus a mutual chain of connexion between the organs and the humours, one being essential to the operations of the other.

This union of fluid and solid parts produces a peculiar structure, which is the most efficient element of animal organization. It consists of a soft, areolated, and elastic texture, which, more or less modified, constitutes the entire substance of some of the inferior animals, and in all it enters so largely into their composition that it produces, as it were, the mould of the entire body and of its individual parts, so that if it were possible to remove those peculiar matters, which are met with in the more perfect creatures, there would still remain a substance, retaining in an extraordinary manner, the form and figure of the original animal. This substance, which is the common cellular membrane, is condensed upon the external surface, so as to form the covering called skin; whilst in the interior, being modified and somewhat more complicated, it gives rise to the mucous membrane. Thus the substance of the body is contained between the skin and the mucous membrane.

In most animals another solid is found, totally different from the cellular tissue, namely, the muscular fibre. It forms the basis of the muscles which are furnished for the production of the various motions of the body.

The nervous fibre is another solid, equally distinct from the cellular and the muscular; it constitutes the basis of the nervous system, which is the instrument of sensibility.

These three substances, the cellular, the muscular, and the nervous, form, by their various combinations and modifications, the different organs of the animal body. These may be now very briefly enumerated. Every animal, with the exception probably of some of the animalculæ, possesses an external skin, an internal mucous membrane which forms the organ of digestion, and a spongy cellular tissue contained between them. In most animals there are vessels, by which the nutritive matter, absorbed from their digestive apparatus, is carried to every part of the body; in many animals there are organs of secretion, in which this matter is purified by losing a portion of its substance; and also internal organs of respiration, which are either dispersed in the form of tracheæ, or concentrated in that of gills or lungs; in each case the nutritious fluid is subjected to the influence of the atmosphere, and in consequence undergoes several important changes. The preceding structures, with the exception of the skin, are subservient to the process of nutrition.

The greater number of animals are provided with muscles for voluntary motion; senses, for the reception of external impressions; nerves, for the transmission of sensation and volition; and, lastly, in many species, there is a brain, the organ of perception and volition.

All animals are capable of reproduction; but all do not possess distinct organs of generation; in most instances, however, there are male and female organs, which are either united in one animal, producing a complete hermaphrodism, or they are divided between two individuals, so as to give rise to the distinction of the sexes.

The form of every animal body, although it is more or less rounded, presents an almost infinite variety in the different species, each of which has a configuration proper to itself. In several of the lower classes, the body presents a radiated disposition, so that its different parts are placed around a common centre. In all the more perfect animals, the body is very exactly divided by a median and perpendicular plane, into two equal and symmetrical halves. This division is not restricted to the surface, but extends into many of the internal parts of the body.

There are certain modifications of the external form, which have an immediate influence on the exercise of the animal functions; for example, in the superior classes the body is divided into a head, a trunk, and extremities.

The head, which is often subdivided into the cranium and face, contains the great centre of the nervous system, the organs of peculiar sensations, and also of mastication. The trunk is usually separated into two great cavities, called the chest and the abdomen; in the former, the central organs of the circulation of the blood and of respiration are lodged; in the latter are contained the principal parts of the apparatus of digestion, of the secretion of urine, and of generation. Many peculiarities are exhibited in these divisions; for instance, in some animals, the body possesses but a single cavity, which contains all the organs, particularly those of digestion; in others, a distinct head is added, whilst others have a thorax either separate from the head and abdomen, or confounded with these cavities. The vertebrated animals, who enjoy the most perfect organization, have always a distinct head, although the chest and abdomen are sometimes confounded.

The extremities or appendages are even more diversified in their disposition than the trunk of the body. The radiated animals have certain appendages around the mouth, called tentacula, which are destined to motion and to feeling. The antennæ of the crustacea and insects appear to be organs of sensation. In most animals the appendages are placed in pairs upon the sides of the body, and are more especially devoted to motion; their number is various, but in the vertebrata, there are never more than four members.

In concluding this review of the organization of animals, I shall offer a few remarks on the functions which they exercise. All organized beings exhibit certain phenomena, to which, taken collectively, is given the term of Life. This forms a marked distinction between organized and inorganized bodies. The former are, like the latter, subjected to the influence of the general properties of matter; but this influence is modified and controlled by the principle of life.

The animal functions have been variously arranged by writers on physiology, but as I shall have occasion hereafter to notice some of the most celebrated of these classifications, I shall in this place merely point out the arrangement which appears to be the most judicious. These phenomena may be divided into two great classes: 1. Those which are connected with the individual. 2. Those which belong to the species. The first include the functions of nutrition and of external relation, and the second those of generation.

Nutrition, which is common to all organized bodies,* is a simple process in the lowest animals; but it becomes complicated in the more perfect species. This complexity results from the endowment of voluntary motion, which, by preventing the direct absorption from the earth of particles ready prepared for nourishment, a process which occurs in plants, renders it necessary that the alimentary matter of an animal should be introduced into its body, in order to undergo those changes by which it may be fitted for nutrition. The principal function by which these changes are effected, is digestion. The food in every animal, with some unimportant exceptions, is received into their intestinal structure, in which it is influenced by certain juices; so that one part, the chyle, is separated from the mass and then absorbed; it is subsequently exposed to the influence of the atmosphere, and is thus converted into a proper nutritious fluid, which is usually observed under the form of blood. In order to purify the nutritive fluid, it is necessary that its effete parts should be separated; this elimination is accomplished by the various secretions.

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* See p. 4.

The real nature of nutrition and the mechanism by which it is effected, are but very imperfectly understood. The little success that has attended the best directed attempts to penetrate the mystery of this wonderful process, ought not to excite our surprise, when we reflect upon the extreme minuteness of the instruments employed in it, and upon the diversified character of the various substances which are elaborated from the common mass of the circulating fluids. Our knowledge of nutrition is in fact limited to the observation of its effects: we only know that in the higher classes of animals, the blood is the common source from which the particles required for the support of the different organs, however dissimilar they may be, are derived; and a decomposition takes place in the ultimate vessels, by which means a portion of the blood becomes solid and is deposited in the substance of each organ of the body, whilst a part of the organ, whatever it may be, becomes fluid and is carried into the torrent of the circulation. This reciprocal action of composition and decomposition, is essential to the preservation of the vital actions, so that a very short suspension of it proves destructive to life. The activity of the process varies in the different epochs of existence; in the commencement, the deposition of nutritive matter exceeds in quantity the absorption of old particles; it is upon this excess that the phenomenon of growth depends. In the adult period, when the body is perfectly formed, there is an equilibrium of action. In the advance of age, the power of absorption surpasses that of deposition, so that the bulk of the body is considerably diminished. This formative process may be justly regarded as the most important operation of the economy, for it is not only essential to the developement and preservation of the animal body, but it is equally required in the reparation of the effects of accident and disease.

The second class of functions connected with the support of the individual, are those by which the external relations are established with surrounding objects. They are entirely confined to the animal creation, upon which they bestow a new kind of existence totally distinct from mere vegetative life.

The animal functions, or those of relation, result from two great properties, sensibility and contractility: upon these powers equally depend the simple phenomena exhibited in the polypus, and the complicated operations in man. In some animals sensibility is confined to the perception of impressions which are made upon the surface of the body; and motion, to the general contraction which is the result of those impressions. But in most classes there are organs for the exercise of special sensations, by means of which, ideas of the properties of surrounding bodies are acquired. These bodies make impressions either upon the skin or upon the peculiar organs of sense, which are transmitted by the nerves to the central mass of the nervous system, where perception takes place. This last organ is also the seat of those mental properties, such as memory, association, imitation, &c., which are enjoyed by animals.

In the inferior tribes of animated beings the phenomena resulting from contractility, are few in number and simple in character. But the superior animals, which are endowed with a more perfect organization, have the power of exercising the most complicated motions with astonishing ease and rapidity: thus they can produce, by an effort of volition, the most trifling movement of each individual part of the body, or a change in the position of the whole machine. The muscles are the material and obedient agents by which these commands of the will are accomplished. They are also connected with various other actions, and in those creatures who breathe by the concentrated organs called lungs, they are especially the agents of the voice.

We have in the last place to consider the functions which are destined for the preservation of the species, namely, those of generation. As death is the natural and invariable termination of life, the organized world must soon have ceased to exist, if the Almighty Being, in his infinite wisdom, had not provided for the renovation of the different tribes of animals and plants.

Every living being is endowed with the faculty of reproduction. This faculty, which is inseparably connected with organization, is exercised in so diversified a manner that it has no character which is proper to, nor any thing which is common to, all animals.

In many respects, especially among the lower animals, the process of generation is similar to that of vegetables. Several classes have no particular organs, but the body is divided into parts, each of which acquires the properties of the whole; thus the millepede has been observed to divide spontaneously into two portions, upon the smaller of which a head and a tail were subsequently formed.*

In the animals rather higher in the scale, generation is accomplished by means of germs, which are attached for a certain period to the parent, and are then separated, and acquire an independent existence; there are, however, no distinct organs. In the vertebrata, and in many classes of the mollusca and articulata, there are special structures provided for the process of reproduction, which are called the sexual organs. By the operation of the female organs certain bodies called ova are formed; these eggs, being influenced by the organs of the male, are capable of commencing an action within themselves, by which the embryo of a new animal is produced. The ovum is either retained in the body of the parent until the new being is sufficiently perfected to sustain an independent existence, or it is discharged at an early period, and in this case the embryo is developed by the operation of external circumstances.

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* Trembley, Mémoires pour l'Histoire d'un Genre de Polypes. Beclard, Anatomie Générale, p. 29.

In concluding this sketch of animal organization, I am anxious to impress upon the mind of the reader, that every attempt which is made to divide and arrange the organs and functions of animated beings, must, from the inseparable connexion which exists between all parts of the living body, be imperfect. Thus, the process of nutrition has an influence on that of generation, whilst both are modified and assisted by the operations of the nervous and muscular systems. On the contrary, the animal functions are affected by the organic, and depend on these for their support. We may agree, then, with a distinguished writer,* when he says, that in animals whose organization is very greatly developed, life appears essentially to consist of the reciprocal action of the central organ of the vegetative functions, the heart, and of the principal organ of the animal functions, the brain; of the circulation, and of the nervous action, or of the action of the blood upon the nervous system, and of the nervous system upon the organs which move the blood. The other phenomena support these two principal actions, which may be regarded as the two essentially vital functions of animals.

SECTION IV.

OF THE HUMAN BODY.

MAN, although the most perfect product of the creation, has a body which closely resembles, in its internal structure and vital phenomena, that of the inferior animals. The preceding observations lead, then, in a natural order, to the examination of the human organization, which is the immediate object of the present work.

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* Beclard, loc. cit., p. 18.

The investigation of the human frame presents two points for consideration: 1. The external configuration or form. 2. The internal composition or texture.

The human body, like that of all organized beings, has a rounded form, which is not only evident in its external contour, but also in its different organs, and even in the minute particles of which these are composed. This rotundity depends principally on the large proportion of fluids which enters into the composition of animals. This is seen in the young child, in whom the limbs, the face, &c., are distinguished by their rounded form; whilst, in old age, when the humours are considerably reduced in quantity, the body loses much of its original form, and becomes unequal and irregular upon the external surface.

The length of the human figure greatly exceeds its breadth and thickness. The degree of this excess is subject to variation in the different epochs of life, and also according to the robustness and embonpoint of the individual. This disposition is most developed in the extremities, where the bones, muscles, vessels, and nerves are distinguished by their length. It is, however, frequently met with in the trunk. Some anatomists have endeavoured to prove that there is a radiated arrangement of the organs, but, although the vascular and the nervous systems do, in some degree, observe this order, yet it would be incorrect to receive it as one of the characteristics of the human form.

In all the superior animals, and consequently in man, there is a marked symmetry in the exterior and partly in the interior of the body, so that we may regard the body as being divided into two lateral and corresponding halves.

The symmetry is not equally defined in all parts of the body; it is most distinct in the organs which belong to the animal functions, and least so in those which are connected with nutrition. Thus the bones, the muscles, the nerves, and the organs of the senses are double; whilst the stomach, the intestines, the liver, the spleen, &c. are single. There are, however, many exceptions to this law; for example, the lachrymal glands, the salivary glands, the mammæ, the testicles, the kidneys, and the blood-vessels are nearly symmetrical. There are several parts which are more symmetrical at the period of their formation than afterwards; thus the liver is at that time more equally divided by its broad ligament; the heart is placed more perpendicularly in the chest, and its two sides nearly correspond in their size and in the thickness of their parietes.

This division of the body is effected by a vertical plane, which we may imagine to be placed exactly in the median line. This plane forms on some parts of the external surface, a peculiar appearance, which is termed raphé; as the raphé of the perinæum, of the scrotum, &c.

In many of the internal parts there is a partition instead of a mere line of demarcation. This is seen in the spines of the frontal and occipital bones, in the falx major, in the septum lucidum, in the septum narium; there are also traces of it in the mediastinum, the suspensory ligament of the liver, &c. These different lines and partitions indicate the places at which the two sides of the body and of the various organs, which are separated in the embryo, are subsequently united.

There are several organs placed on the median line, which have not at first sight a symmetrical appearance, but which possess it in principle; we have examples in the tongue, in the larynx, in the thyroid gland, in the prostate gland, in the heart, and even in the vertebral column.

The analogy between the upper and lower parts of the body is not so strongly characterized, as that which we have traced between the lateral parts. Still it is certain, that the divisions of the upper extremity have considerable resemblance to those of the lower: thus the arm corresponds to the thigh, the fore-arm to the leg, and the hand to the foot. The differences which are observed between these parts, depend on the diversity of function of the upper and lower limbs. Some anatomists have also compared, but with little reason, the lumbar portion of the spine with the cervical; the large vertebræ of the sacrum with the bones of the head; and the os coccygis with the lower jaw. The comparison has even been carried so far, that it is said, by Meckel, the apparatus of respiration is comparable to the urinary; and the thyroid gland, the thymus gland, the tongue, and the nose, to the organs of generation. This appears to be forcing a resemblance which does not exist in nature. The same anatomist also contends for an analogy between the anterior and posterior surfaces of the body, and with this idea he has compared the sternum and linea alba to the vertebral column. This comparison is as objectionable as the last.

The details which I have mentioned, sufficiently prove that the body has a symmetrical form. But in demonstrating this fact, it is not pretended that the symmetry is mathematically correct. There are many exceptions to it, and in some respects it is particularly imperfect.

The human body is divided into three parts, viz., the head, the trunk, and the extremities. The first distinguished by its rounded figure, is placed on the upper part of the trunk, on which it is supported. It lodges the central organ of the nervous system, the organs of the senses, with the exception of that of touch, and the organs of mastication. The second part, or the trunk, is flattened anteriorly and posteriorly. It consists of the vertebral column, of the thorax, and of the abdomen; the first contains the nervous mass, which is called the spinal cord; the second receives the central organs of the circulation and of respiration, and the third encloses the apparatus of digestion, of the secretion of urine, and of generation. The extremities, which are four in number, are distinguished into the superior or thoracic—and inferior or abdominal. They are characterized by their length, which greatly exceeds their other dimensions. These members are divided into several parts, which are joined together in the numerous articulations, in such a manner, as to be admirably calculated for varied and extensive motion.

The different parts of the head, trunk, and extremities are subdivided into a certain number of regions, the situation and the extent of which, are principally determined by the bones. A perfect knowledge of the relations of these regions is indispensable to the surgeon, as it forms the most certain guide to the situation of the various and important organs which are concerned with the performance of the different operations. The study of this branch of our science belongs to what has been judiciously called, topographical anatomy.

The human body consists of an assemblage of fluid and solid parts, which have a mutual influence on each other, and which experience at every moment of their existence, certain important and necessary changes. They are so intimately combined with each other in the organs of the body, that it is impossible to effect an entire separation between them. The nature of this combination, which no art can imitate, is but imperfectly understood; it doubtless depends upon the influence of life, so that when this is destroyed, the union which had previously existed begins to yield to chemical agents, and the decomposition of the organic textures is the speedy result.

In studying the wonderful structure of our frame, we should observe the same method as in investigating the nature of any other material body: that is to say, we should endeavour to separate the fluid from the solid parts; we should examine these individually, in order to ascertain their properties, their differences, and their uses; in fact we should analyse, as far as this is possible, the animal body, so as to determine the nature of its constituent parts. This mode of procedure is well calculated to unravel the intricacy of the human organization; but in order to complete our knowledge of the disposition and operations of this complicated machine, it is necessary to reverse the method of examination; to trace, in a synthetic order, the various combinations of the fluid and solid materials; to study the properties and uses of the different organs; and, lastly, to compare the relations that exist between them, so that the share which each enjoys in the production of the vital phenomena, may be properly distinguished.

The researches of animal chemistry, to which anatomy and physiology are so deeply indebted, have shewn that the human body is composed of a great number of elementary substances, which are termed its ultimate principles. The exact number of these simple materials has not yet been determined, but the following are generally admitted :—

ELEMENTARY SUBSTANCES.

1. Azote.
2. Carbon.
3. Oxygen.
4. Hydrogen.
5. Phosphorus.
6. Calcium.
7. Sulphur.
8. Sodium.
9. Potassium.
10. Magnesium.
11. Iron.
12. Chlorin.
13. Manganese ?
14. Silicium ?
15. Fluorin ?
16. Iodin ?

The combination of these elements in different forms and proportions, produces certain compounds which are called the immediate or proximate principles of formation. They vary considerably according to the age of the individual, the state of health, and other circumstances; so that it is very difficult to ascertain what number really belongs to the composition of the healthy body.

PROXIMATE PRINCIPLES.

1. Gelatin.
2. Albumen.
3. Fibrin.
4. Colouring Matter of the Blood.
5. Fatty Matter..
    - Olein.
    - Stearin.
    - Cholesterin.
6. Mucus.
7. Urea.
8. Picromel.
9. Sugar of Milk.

ACIDS.

1. Phosphoric.
2. Uric.
3. Carbonic
4. Sulphuric.
5. Muriatic.
6. Benzoic.
7. Oxalic.
8. Acetic.
9. Butyric?
10. Purpuric?
11. Malic?

The arrangement of these constituent principles, and the form they present in the fluid and solid parts of the body, have, for a considerable period, occupied the attention of the most celebrated anatomists of Europe. Of the various means that have been adopted to elucidate this subject, none have been so extensively employed as the microscope. The magnifying powers of this instrument, by enabling us distinctly to perceive the most minute particles of matter, have thrown great light on the intimate composition of organized bodies. But in acknowledging the advantage which has been derived from microscopical researches, it is important to state, that much of their value is destroyed by the frequent contradictions they exhibit in their results. These discrepancies have proceeded from several causes, of which the most influential are the imperfection of the instruments that have been employed, and the optical deceptions that have so frequently misled even the most skilful experimentalists. In the present day this uncertainty exists to such a degree, that few points concerning the intimate textures of the body can be considered as firmly established; and, therefore, the reader must receive with caution all deductions that are derived from this source.

We are indebted to J. F. Meckel, the celebrated professor of anatomy in the University of Halle, for some important observations upon the minute texture of the animal organization. In his excellent Manual of Anatomy,* in speaking of texture, he says:—" It is possible to reduce the compound parts into substances that are more simple, and which in their turn differ from each other according to their degree of simplicity. The ultimate constituent parts may be reduced by analysis into two substances; one of these possesses a determined form, which is not the case with the other, although this is also capable of configuration. These substances consist, one of globules, and the other of a matter which is susceptible of coagulation. The latter substance, either by itself or united with the globules, forms, when it is liquid, the fluids, and when it is coagulated, the solids of the body. These two material elements are not both contained in every fluid or solid; the globules, however, are never met with by themselves; they are always plunged in the midst of the coagulated or coagulable substance.

" The name of globules is not strictly applicable to the above mentioned particles, for it is proved that many of them, especially those of the blood, have not the same thickness in every direction, but that they are flat and lenticular. However they are every where rounded, never being found angular; but their form, their volume, their number, their colour, and their chemical composition neither resemble each other in different subjects nor in different parts of the same subject; they also vary according to the period of life; so that the above characters are transient, and liable to irregularity. Thus, with respect to form, the globules appear to be more compound in some parts than in others. In the blood they are composed, according to many observers, of a central solid part, and of a hollow and vesicular part, which encloses the former without adhering to it. Every where else their structure appears to be more simple, for we only perceive in them one of these two parts; but whatever may be the region of the body in which they are examined, we distinguish that their general form is every where the same in the same animal; that is to say, they are never found oblong in one place and round in another. In man they are rounded.

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* Manuel d'Anatomie, Générale, Descriptive, et Pathologique. Translated into French by M. M. Jourdan and Breschet.

"With respect to their size, the globules differ very much in the various parts of the body; they are smaller in the substance of the liver than in the kidneys or spleen. Those of the nervous substance are of a smaller size than those of the blood; the latter are also larger than those of lymph, of milk, or of chyle. Their number is also variable; thus there are more in the blood than in chyle or milk. In some solids they are entirely wanting, as in the cellular tissue, in the fibrous, cartilaginous, and osseous textures. On the contrary, they are numerous in the nerves and muscles.

"The colour and chemical composition of the globules, are generally determined by those of the parts in which they are placed; this is evident, since the latter are formed by the former."

I have made this extract, because it presents the opinion of one of the first anatomists of Europe; but it is doubtful if some parts of it are correct, at least they are directly opposed in several respects to the careful investigations of M. Milne Edwards,* in

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* Recherches Microscopiques sur la Structure Intime des Tissues Organiques des Animaux. Extrait des Annales des Scien. Nat. 1826. The observations of Dr. Edwards were originally published in 1823.

France, and to those of Dr. Hodgkin, in England. The former thinks that he has established the following laws :—

1. That the elementary structure of the following tissues is identical in all animals; viz., the cellular, the fibrous, the vascular, the muscular, and the nervous.

2. That this elementary structure is globular, the globules having the same form and the same size, whatever may be the animal or organ in which the above tissues are examined. He considers these corpuscles to possess a spherical form, each having a diameter of $\frac{1}{300}$ of a millemetre.

The observations of Dr. Edwards are the results of such cautious and repeated examinations, that it is scarcely possible to doubt their accuracy. In the year following their publication, they were, however, called in question by Dr. Hodgkin.* This gentleman, who has employed a most perfect microscope, constructed by Mr. Lister, denies the globular structure of those tissues, which have been supposed by the highest authorities in these matters, to possess that arrangement in an eminent degree; for example, the muscular, nervous, and cellular fibres. I have had several opportunities of examining the elementary tissues, by the kindness of my friend Mr. Cooper, lecturer on chemistry, who is in possession of a very excellent microscope. As I shall have occasion in the subsequent parts of this work, to allude to these observations, it is only necessary to remark in this place, that their general results exactly correspond with the statement of Dr. Hodgkin.

* Annals of Phil., Aug. 1827.

SECTION V.

OF THE FLUIDS, OR HUMOURS.

THE fluids first require our attention, on account of their importance in the animal economy. They are contained in the solids, of which they determine the volume, the form, the density, and in general the physical properties. They enter into the formation of every part of the body, however dense it may appear. They are in most instances combined with the solids, as in the substances of the different organs; in other places they are merely in juxta position with the latter, being contained in the canals which these describe; such is the case in the vascular system, in the excretory tubes, &c. The humours, although they are so universally diffused, vary almost indefinitely as to their proportion in the different regions of the body. There is also great variation in the different periods of life. In the first stage of existence, the embryo is almost entirely composed of fluids. As growth proceeds, the solids are added, and the body acquires considerable firmness. The deposition of solid and the absorption of fluid matter continue, so that, in extreme old age, the animal frame becomes firm and condensed; this change, which is the natural attendant on the advance of years, explains many of the phenomena which are then observed.

It is impossible to form an exact estimate of the above proportion, because, whatever means are employed, we cannot entirely separate the fluids from the solids; and, in addition, there are many solid parts which readily become liquid; so that, in the process of desiccation, they are confounded and dissipated with the fluids. Several experiments have been made to determine this question. Professor Chaussier placed a corpse, weighing 120lbs., in an oven. When it had been desiccated during several days, he found that the weight was reduced to 12lbs. If this was received as a sufficient test, the proportion in the adult of the fluids to the solids would be ten to one. The examination of an adult mummy gave even a greater proportion, as its body weighed only $7\frac{1}{2}$lbs. Richerand says, the fluids form about 5-6ths of the whole body.

A correct classification of the various humours has always been considered of importance, in consequence of their great influence in the production of all healthy and morbid phenomena. The ancients divided them into four classes: viz. the blood, the lymph, or pituita, the yellow, and the black bile. Many attempts have been made in modern times to establish a correct arrangement of the animal fluids, but few, if any of them, are entirely free from objection. Several chemists have classed the humours according to their peculiar composition. Thus Fourcroy admitted six classes:—1. The saline fluids. 2. The oily fluids. 3. The saponaceous. 4. The mucous fluids. 5. The albuminous. 6. The fibrinous. Professor Chaussier* founded his division of the humours upon the mode of their formation:—1. The circulating fluids, comprising the blood and the lymph. 2. The perspired or exhaled fluids. 3. The follicular fluids. 4. The glandular fluids. 5. The fluids produced by digestion; namely, the chyme and the chyle. This classification, which is decidedly the most scientific and perfect that has been constructed, has been very generally adopted by the physiologists of France, and, amongst others, by M. M. Magendie* and Adelon.†

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* Table Synoptique des Humeurs.

The classification which I have recommended in my lectures, is founded upon that of Chaussier. According to this arrangement, the humours may be divided into four great classes:—1. The fluid which forms the blood. 2. The blood. 3. The fluids which are formed from the blood. 4. The fluids which are returned to the blood. The first class includes only the chyle, the product of digestion, and which was so emphatically called by Hunter, the seed of the blood. The second class includes the arterial blood and the venous blood. The third class comprehends fluids of very different characters; they all, however, resemble each other in being formed from the blood. The last class includes only the lymph, which is the residue of nutrition, and which, although it is always described by the same name, and is, by the majority of persons, also regarded as being always the same fluid, is in itself an extremely compound substance, and is rarely composed of exactly the same materials.

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* Compendium of Phy., 3d edit. of Dr. Milligan's translation, p. 13.

† Phy. de l'Homme, tom. i. p. 118.

TABLE OF THE ANIMAL FLUIDS.

1. The Chyle.			
2. The Blood.	Arterial. Venous.		
3. The Fluids formed from the Blood.	Perspired or Exhaled Fluids.	Recrementitial.	1. Of the Serous Membranes, including that of the Synovial Membranes (and of the Lining Membrane of the Vascular System?) 2. Of the Cellular Tissue. 3. Of the Adipose Tissue, including the Medullary Membrane. 4. The Colouring Matter of the Skin, of the Hairs, of the Iris, and of the Choroid. 5. The Aqueous and the Vitreous Humours, and the Liquor Morgagni. 6. The Fluid of the Labyrinth, or the Liquor Cotunni. 7. The Fluids of the Fœtal Membranes: *a*, the Liquor Amnii; *b*, the Liquor Chorii; *c*, the Humour of the Vesicula Umbilicalis.
		Excrementitial.	1. Of the Skin. 2. Of the Mucous Membranes. The Mucous Membrane of the Uterus, furnishes—*a*, the Menstrual discharge; *b*, the Lochial discharge.
	Follicular Fluids.		1. Of the Sebaceous Follicles. 2. Of the Ceruminous Glands. 3. Of the Meibomian Follicles. 4. Of the Lachrymal Caruncle. 5. Of the Mucous Follicles. 6. Of the Tonsil Glands. 7. Of the Prostate Gland. 8. Of the Seminal Vesicles. 9. Of Cowper's Glands. The Follicles of the Mucous Membrane of the Uterus furnishes the matter of the Deciduous Membranes.
	Glandular Fluids.		1. Of the Lachrymal Glands. 2. Of the Salivary Glands, including that of the Pancreas. 3. Of the Liver. 4. Of the Kidneys. 5. Of the Testicles. 6. Of the Mammary Glands.
4. The Lymph.			

I shall now proceed to give a summary view of these fluids.

The chyle is a whitish fluid, which is separated in the intestines from that pulp called chyme, into which the food is reduced by the digestive process. The appearance of the chyle varies in some degree according to the kind of aliment from which it is formed; thus it is of a milky whiteness when it is extracted from animal or vegetable substances, of a fatty nature; whilst it is almost transparent when it is derived from food which contains no fat. The colour becomes somewhat more decided, and has a rosy tint, after the chyle has passed through the mesenteric glands. It acquires, however, its deep red colour as it circulates within the lungs. I have frequently observed the effect of exposing chyle to the influence of the atmosphere; in a short time the fluid assumes a rosy colour, which becomes deeper as the exposure is continued.

This fluid, which has a great resemblance to the blood, undergoes, when it is removed from its containing vessels, a spontaneous coagulation, and divides into three parts: the one solid, which remains at the bottom, another liquid, at the top, and a third that forms a very thin layer on the surface of the liquid; the last is less distinct in the chyle which is formed from food containing no fat.* The liquid part is similar to the serum of the blood, and the solid part is formed of fibrin and a little colouring matter.

The chyle, examined by the microscope appears to consist of a thin fluid, which contains an immense quantity of globules; these differ from the particles of the blood in being smaller and in being white, or at most slightly tinged with red. They are of different sizes, and, according to Mr. Bauer, they are enlarged as they traverse the mesenteric glands. Prevost and Dumas have observed in the chyle of the rabbit, the dog, and hedgehog, globules of $\frac{1}{6720}$ of an inch in diameter, very similar to those perceived in the blood.

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* Magendie, Compend. of Phy., p. 297.

The chyle is, in all probability, completely assimilated with the blood, as it passes through the pulmonary circulation, although many important and necessary changes are effected in it before it reaches the lungs, more especially as it traverses the glands of the mesentery.

It is impossible to form any accurate estimate of the quantity of chyle which is formed in any given time, in consequence of the difficulty of obtaining it, free from intermixture with the lymph. There can be no doubt, however, that the quantity is very considerable, as a large proportion of the blood is constantly expended in performing the numerous secretions, and in keeping the organs in a state of health by means of nutrition. A fact is mentioned by M. Magendie, which will assist the judgment in this matter. He states that he obtained, from the thoracic duct of a middle-sized dog, half an ounce of fluid in five minutes; this, of course, was not pure chyle, as there must have been a considerable quantity of lymph mixed with it.

The chemical composition of chyle has been examined by Vauquelin, Marcet, Prout, &c. It appears that the quality of this fluid varies in the different parts of its course. Dr. Marcet* found that chyle formed from vegetable food is nearly transparent, and that it is only slightly tinged of a red colour by exposure to the atmosphere; it also resists decomposition for a considerable period, which is probably owing to the large quantity of carbon which it contains. The chyle from animal matter is white and opake; it acquires a bright pink colour from contact with the atmosphere, and containing less carbon, and much more of the carbonate of ammonia than the preceding, it is soon decomposed. The chyle contains a fatty substance, which is considered by Dr. Prout to be incipient albumen; it also possesses the same salts that exist in the blood.

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* Med. Chir. Trans. vol. vi.

The blood, or the nutritive fluid, is of such immense importance in the economy, and is of such an extremely complex nature, that the full investigation of all its properties would require a larger space than the limits of this work will allow. The many excellent works which have been published upon this subject, more especially that of Hunter, render any detailed account unnecessary. I shall therefore confine myself to a general description of the circulating fluid.

The blood is a very compound substance, consisting of a colourless fluid, in which are suspended numerous red particles. It is generally admitted that it contains three distinct substances; viz. the serum, the fibrin, and the red particles. Lately, some distinguished physiologists have asserted that there are only two substances—the serum and the coloured particles, each of the last consisting of a central white corpuscle, enveloped in a coloured matter. We shall again have occasion to allude to this opinion.

The blood is contained in the heart and the blood-vessels, by which it is propelled and conveyed into every organ of the body, forming all its individual parts, and preserving them in a state of health. It has a peculiar odour, and rather a nauseous taste. The colour of the blood, in the superior animals, is red. This colour, however, appears to be not an essential property, as there are many classes in which the circulating fluid is colourless; and even in the human subject, there are several organs whose vessels do not admit the red particles. In man, who possesses a perfect double circulation, the colour of the blood is very different, according as it is contained in the arteries or in the veins; in the former, it is bright scarlet; in the latter, it is dark or modena red. The cause of this difference of colour has been variously explained by physiologists. Some have thought that it depended upon a larger quantity of iron being contained in the venous fluid; that substance, however, is found in an equal proportion in the arterial blood. There is every reason to believe that the excess of carbon which is mixed with the venous blood, is the real, or at least the principal cause of its purple colour. This is proved by observing, as in the experiment of Mr. Hunter, the change effected in the venous fluid whilst it circulates through the pulmonary organ; or by attending to the alteration which takes place in exposing the under part of a coagulum to the action of the air. In each case, after the dark blood has been influenced by the atmospheric air, it is changed into the light-coloured fluid which is seen in the arteries. Now, as the principal phenomenon produced by the contact of the air with venous blood, is the extrication of a considerable quantity of carbon in the form of gas, we may conclude that the loss of this substance is the cause of the scarlet hue in the arterial fluid, as its presence is of the modena colour in the venous blood.*

The specific gravity of the blood exceeds that of water in the proportion of about 1,050 to 1,000; it varies from 1,050 to 1,126. It is probable that Haller committed an error, when he calculated the weight as high as 1,527. It has been ascertained, that the venous fluid is rather heavier than the arterial; the difference appears to depend upon the excess of carbonaceous matter in the former. The weight of the blood is often altered by disease; in one instance it was as light as 1,022.

The temperature of this fluid is nearly the same as that of the interior of the body. It is usually 98° of Fahrenheit's thermometer, varying to 102°, which it seldom exceeds. The heat of the blood is rarely increased during internal inflammation; instances, however, are related, where, in fever, the temperature of the body has been noted at 107°, and in tetanus at 110°.† In external inflammation, there is an increase from 4° to 7° in the temperature of the part. In the cold fit of ague, the heat of the blood has been reduced as low as 94°. The blood contained in an artery is warmer than that which circulates in a vein; the mean capacity for caloric of arterial blood being, according to Dr. Davy, to the capacity of venous blood, as 900 to 872.

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* The investigations of Hewson prove the effect of air in changing the colour of the blood. I shall quote one of his experiments, which is decisive upon this subject. Having laid bare the jugular vein of a living rabbit, he tied it up in three places; then opening it between two of the ligatures, he let out the blood, and filled that part of the vein with air. After allowing it to rest till the air became warm, he took off the ligature which separated the air from the blood, and then gently mixed them together. He observed that the venous blood assumed a more florid redness, where it was in contact with the air bubbles, whilst in other parts it remained of its natural dark colour.—*Exper. Inquiry*, vol. i. p. 8.

† Dr. Elliotson's Trans. of Blumenbach, p. 158. Wilson's Lectures on the Blood, p. 16.

The quantity of blood which circulates within the body, cannot be ascertained with any degree of accuracy. It is impossible, whatever are the means employed, to remove the whole of this fluid from its containing vessels, so that if an animal be deprived of all the blood which can be extracted, a very large proportion still remains in the small vessels and in the substance of the organs. But even if the whole of the blood could be removed, the age, the temperament, the state of health, and many other circumstances, so greatly influence its proportion, that no other than a very general conclusion could be formed. The illustrious Harvey calculated the quantity of the blood as being $\frac{1}{20}$ of the whole body. It was stated by Haller, that about fifty pounds of fluids circulated in the body, of which about twenty-eight pounds consisted of red blood.

Sir A. Cooper performed some experiments, from which he concluded, that the blood constituted from $\frac{1}{16}$ to $\frac{1}{20}$ part of the body. The estimate of Haller is probably nearest the truth, but even that can only be regarded as a general calculation. It is almost needless to state, that Keil committed a great error when he estimated the quantity of blood at one hundred pounds.

In defining the blood, we have, in accordance with the commonly received opinion, called it a *fluid*. There is considerable doubt if we can strictly apply that term to the blood; because, when it is observed through a microscope, we perceive that a considerable proportion of it consists of *solid particles*, which float in a transparent liquid. It is then, at least, a very compound and viscid fluid, and can, as we shall immediately learn, be very readily converted into a solid substance. The suspension of the solid particles in the transparent humour, is a wise provision of nature, by means of which the blood is readily propelled through the flexible canals, which convey it to each texture of the body, thus allowing of those separations and divisions of its mass which are required for its passage through the minute vessels, and for the performance of secretion and nutrition.

The blood, when it is removed from the living body, becomes solid; and, indeed, whilst it remains within it, solidity is a most essential and necessary property of one of its component parts. The process by which the blood is changed into a solid, is called its coagulation. It is by means of this process, that the hard parts of the body are formed from the blood, and are afterwards by a continued deposition, preserved in a fit and healthy condition. Coagulation is equally necessary for the production of union by adhesion and by granulation. Such being the importance of this process, we shall describe the principal phenomena connected with it.

When the blood is removed from its vessels, an aqueous vapour arises from it during the time it preserves its heat. This, which is called the halitus of the blood, has a fetid odour resembling, according to Haller, that of sweat or urine. It consists of hydrogen and carbon, mixed with which Dr. Bostock has detected a small quantity of animal, and even of saline matter, which renders it capable of undergoing putrefaction.

It was the opinion of Mr. Hunter, that no caloric was evolved during the coagulation of the blood. The reverse, however, has been proved by several observers. Fourcroy relates an experiment in which there was an increase of heat to the amount of 11°. The late Dr. Gordon confirmed this; the increase in one of his experiments being 6°. Dr. Davy, and others, however, state, that the disengagement of caloric is very slight. Dr. Philip has proved, by direct experiment, that galvanism raises the temperature of arterial blood 3° or 4°; it also renders it dark-coloured. It is remarkable, that the galvanic power has no effect upon the warmth of venous blood.

Whilst the coagulation is proceeding, a considerable quantity of carbonic acid gas is extricated. This was noticed by Sir E. Home, who founded a curious hypothesis on it, with respect to the organization of the fibrin. Dr. Scudamore has also performed some experiments which tend to prove the disengagement of carbonic acid.

The blood, after it is taken from its vessels, remains fluid for a short time; the duration of which is influenced by many causes. Subsequently, it begins to assume the solid form, a thin film being first perceived upon the surface, and afterwards, as the change proceeds, the whole mass is converted into a soft jelly. This soon gives way and divides into two parts; one consisting of a firm cake, and the other of fluid. The first is called the crassamentum, the cruor, or the clot; and the second, which surrounds it, is named the serum.

The concretion usually commences in about 3½ min. after the blood has been abstracted from the body, and the whole is jellied in about 7 min., although often not until 15 or 20 min.; and frequently a much longer period is required, the blood being but partially coagulated in 24 hours. At the end of 10 or 12 min. the serum begins to separate, so that on cutting into the clot at that time, the incisions are immediately filled up with fluid. It often happens, that after the apparently complete separation of the crassamentum from the serum has taken place, the former continues to contract even during several days, thus pressing out and increasing the quantity of the latter.[*] Venous blood coagulates more speedily than arterial, and a small quantity sooner than a large one.

The period of coagulation is greatly influenced by the state of the vascular system. The ingenious Hewson contended that concretion occurs speedily in proportion to the depression of the vital actions; an opposite opinion was entertained by Mr. Hey, of Leeds. We are indebted to Mr. Thackrah, of the latter place, for determining the question by the most conclusive investigations. These consisted in receiving blood from the same animal into different cups in a full uninterrupted flow, and noting the time at which coagulation commenced in each cup: it was observed, that coagulation always began first in the blood which was last removed, and last in that which was first removed.[†] The expe-

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[*] Hunter's Treatise on the Blood and Inflammation, vol. i. p. 33.

[†] Blood was received from a stuck horse, at four periods, about 1½ min. intervening between the filling each cup. Concretion began in

	Min.	Sec.		Min.	Sec.
N°. 1	11	10	N°. 3	9	55
2	10	5	4	3	20

Three cups were filled with the blood of a sheep, at the interval of half a minute—

	Min.	Sec.
1st Cup—coagulation began in	2	10
2d	1	45
3d	0	55

The same result was produced in the human subject. A pound and a half of blood was removed from the arm of a female labouring under fever; a portion of which, received in a tea-cup on the first effusion, remained fluid riments were repeated before Mr. Hey, who admitted that they proved what Hewson had contended for. The conclusion drawn by Mr. Thackrah is, that "the blood coagulates slowly in regular proportion to the tonic state, or that condition of the system in which the vital powers are strongest."*

There is a point of great practical importance connected with the process of coagulation. I allude to the formation of the sizy or buffy coat. This consists of a tough, elastic, yellowish substance, which is placed at the upper part of the crassamentum. Its thickness varies from the $\frac{1}{12}$ to $\frac{1}{8}$ or $\frac{1}{6}$ part of an inch. It is frequently concave or cupped upon its surface. The buffy coat is usually observed in blood which has been abstracted during inflammation, although it is occasionally seen in other states of the system. It is also in most cases formed in venous blood. The late Dr. Gordon was in the habit of exhibiting a specimen of it in arterial blood. I have also had an opportunity, through the kindness of my friend Dr. Tweedie, physician of the Fever Hospital, of seeing the sizy coat imperfectly formed in some blood, which had been taken from the temporal artery of a man labouring under fever. The cause of the formation of this peculiar crust is not well known. Hewson thought, but erroneously, that the blood was attenuated in inflammation, and that the red particles thus more readily subsided into the lower part of the cruor, leaving the lymph or fibrin at the upper part. But, as the quantity of fibrin is actually increased during inflammatory action, some other cause must be sought

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for seven minutes; a similar quantity taken immediately before tying up the arm, was caked in 3 min. 30 sec.

* An Inquiry into the Nature and Properties of the Blood, p. 47.

to explain this phenomenon. It is known that blood, which is taken from a person who suffers from acute inflammation, remains for a longer time fluid than it does under ordinary circumstances. Now, this being the case, the red particles, which are heavier than the lymph, have a longer time to subside to the under part of the crassamentum, and, consequently, to leave the fibrin on the superior surface, where it causes the crust we have been describing. The sizy coat is occasionally present in diseases of debility, especially in scurvy. It is probable, in these instances, that the blood is attenuated on account of the accumulation of serum, and that the explanation of Hewson is here correct.

The cause of the coagulation of the blood is but imperfectly known, notwithstanding the numerous attempts which have been made to discover it. It is needless to enter into the detail of the many experiments which have been instituted, as most of them merely prove what are *not* the causes of coagulation. The exposure to cold and to atmospheric air, and the loss of motion, have each, in turn, been supposed to produce the concretion of this fluid. None of these causes is in the least sufficient to effect the process, although they may more or less assist in promoting it.*

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* That cold is not an efficient cause of coagulation is readily proved. Hewson ascertained that blood might be frozen and afterwards thawed, without coagulation taking place. It appears that the blood most readily concretes at its natural temperature, and speedily at 120°, even more so according to Thackrah, than at the former heat. At 40° or 50° concretion soon begins: between 38° and 32° it generally remains fluid, and at 32° the late Mr. Wilson states that the blood will freeze. It coagulates most slowly between 60° and 90°.

The exposure to air is not necessary, as Hunter found that the blood became coagulated when it was placed in a vacuum. Coagulation also occurs in gangrene, where there can be no direct communication with the atmos-

There are two theories, however, which, from their importance, require a brief notice in this place.

Mr. Hunter,* from observing that the yolk and the albumen of an egg, which are substances devoid of apparent organization, are capable of resisting putrefaction, was led to institute a most interesting set of experiments and observations, which convinced him that the blood was endowed with life. He supposed that the fluid state of the blood depended upon what he termed its living principle; but he also admitted that the fluidity was connected with the containing and living vessels.† The process of coagulation, according to this eminent man, depends upon a vital operation, which bears a singular resemblance to the contraction of the muscular fibre. In certain kinds of death, as in that produced by anger, by electricity, by a blow on the stomach, &c., the blood does not coagulate, nor do the muscles contract. The absence of these two phenomena, which are so constantly observed after ordinary death, appears to result from the sudden and total annihilation of the powers of life in the above instances. The similarity of muscular contraction and the coagulation of the blood, is rendered more striking by the fact, that the chemical composition of fibrin is nearly the same as that of muscle.

The second hypothesis, which is opposed to that of Hunter, has been supported by some experiments performed by Sir A. Cooper, and more particularly by Mr.

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phere. Rest will not produce concretion; for blood which has been fixed between two ligatures in the jugular vein of living animals, has been found fluid at the end of an hour.—*Thackrah, Inq.* p. 62.

* Treatise on the Blood, vol. i. p. 137, *et seq.*

† Ibid. p. 40.

Thackrah. The conclusion which has been drawn from these investigations, is, that the vital or nervous influence of the containing vessels is the cause of the fluidity of the blood; and that the loss of this influence produces coagulation. The experiments of Mr. Thackrah distinctly prove that a portion of blood which is received into a dead vessel, is always more speedily coagulated than when it is retained by ligatures in the living vein. The inference of this fact is, that the vitality of the vessels has an immediate effect upon the blood, and retards its concretion.

In comparing these two hypotheses and the arguments upon which they are founded, the balance is decidedly in favour of the Hunterian doctrine. The blood, while it is contained in the living body, and after it is abstracted from it, exhibits such phenomena in the changes it undergoes, that cannot be explained merely by the operation of mechanical or chemical laws. This position might be supported by numerous proofs, but I shall only quote two of the most striking character. It was shewn by Mr. Hunter, that blood newly drawn from its vessels, requires a greater degree of cold to freeze it, than is necessary to produce the same effect upon a portion of blood which has already been once frozen: in this instance, the blood just taken from the living body, has a power within itself of resisting the effect of a low temperature, which, from analogy, we should conclude depends on vitality. The valuable observations of Dr. Hodgkin afford a second fact, which leads to the same conclusion. He has discovered, that the red particles of the human blood and that of mammiferous animals, arrange themselves spontaneously in piles or rouleaux. He conceives, and I believe justly, that this tendency to arrangement does not entirely depend upon ordinary attraction, but on that of life, because it is different according to the animal used for the experiment, and also because it is diminished when the blood has been some time removed from the body.

The ingenious experiments performed by Mr. Thackrah, instead of disproving the vitality of the blood, as that gentleman appears to suppose they do, powerfully substantiate the contrary opinion. We learn from them, that the blood receives an influence from the living vein in which it is contained; but I think it will be admitted, that the blood must itself be endowed with life, in order that it may be capable of being affected by the nervous influence of its containing vessels; for it is self-evident, that no fluid deprived of vitality can receive any impression from simply being introduced into a living vessel.

In concluding these observations on the process of coagulation, I may state that, although the doctrine of the vitality of the blood may be considered as established, yet it is necessary to admit the direct influence which is exerted over that fluid by its vessels. A mutual sympathy exists between the circulating fluid and the tubes which convey it; a sympathy that is manifest in health and disease, and which, being well understood, would remove much of the contradiction that at present involves the consideration of the question, which I have endeavoured, however imperfectly, to elucidate.

In the preceding pages, the blood has been described as consisting of a common mass. I shall now proceed to consider the different parts of which it is composed, and which are generally admitted to be three in number:—1. The Serum. 2. The Fibrin. 3. The Red Particles. When the circulating blood is examined through the microscope, only two substances can be distinguished, viz. a transparent fluid and the coloured corpuscles. Some continental physiologists contend, that these two alone are the component parts of the blood. Each particle is described as consisting of a central white corpuscle, which is enveloped in a coloured matter; these are united in the blood whilst it circulates, but immediately that it is removed from its vessels, the colouring matter abandons the central white part, and the particles, deprived of their envelope, unite together so as to form what is called the lymph. The more minute examinations that have been made in this country, disprove the existence of such particles as are described above, and have shewn that this new theory is erroneous.

Of the Serum.—This is the fluid portion of the blood, which is separated by the process of coagulation, and occasionally in the interior of the body. It is of a pale yellow, or straw-colour, and often tinged with green. It is frequently of a deeper hue, and more rarely it is of a milky whiteness. The latter appearance has been attributed to an intermixture with chyle, and also to the presence of oil: it is uncertain whether either of these be the true explanation of this phenomenon.

The specific gravity of the serum is subject to variation; but it is always lighter than the fibrin and the red particles. The medium weight is about 1030; in disease it has been met with as low as 1004, and as high as 1080.

The quantity, in the human subject, is affected by the state of the individual; it is less than a half, but more than a third of the whole mass of the blood. Mr. Thackrah says, it bears a proportion to the crassamentum of 1·0 to 1·3. Although the serum is not capable of undergoing spontaneous coagulation, yet it assumes the concrete form by the agency of heat, acids, &c. In order to coagulate serum by heat, 160°, and sometimes 167°, are required. During this process, the albuminous part becomes solid, a large portion of water evaporates, and a small quantity of a thin fluid remains. The last substance was termed, by Senac and Hunter, *the serosity;* it contains some animal matter, which was thought by Fourcroy and others, to be gelatin. This is denied by Dr. Bostock. Serum is also coagulated by spirits of wine, volatile spirits, different acids, and by the oxymuriate of mercury.

The chemical properties of serum have been ascertained by Marcet, Berzelius, and others. It consists of albumen, of water, and of certain salts; sulphur has also been mentioned as one of the component parts, but Dr. Bostock considers the existence of it in the blood, as problematical. The following is the analysis of Dr. Marcet:—Water, 900·00; albumen, 86·80; muriates of potash and soda, 6·60; muco-extractive matter,* 4·00; subcarbonate of soda, 1·65; sulphate of potash, 0·35; earthy phosphates, 0·60 = 1000.

The most important part of the blood is the coagulable lymph, the gluten, or, more correctly, the fibrin. Hunter named it coagulating lymph, to designate its peculiar property of spontaneously coagulating. It consists of a tough, elastic, and whitish substance, which is composed of stringy fibres, laid in striæ, and even in laminæ. Sir E. Home has described in it minute white globules, which are much smaller than the red particles.

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* Berzelius, whose analysis varies but little from the above, says, that the muco-extractive matter is impure lactate of soda united to a portion of animal matter.

The fibrin is transparent whilst it circulates; but when it is coagulated, it is rarely entirely free from the colouring matter, and perhaps never from the serum, the yellow tinge of which is thus communicated to the lymph.

The weight exceeds that of the serum, but it is less than that of the red particles.

The quantity is greatly influenced by the state of the system when it is removed. Berzelius has said, but I know not how correctly, that the crassamentum consists of lymph ·36, and of colouring matter ·64.

The analysis of fibrin is as follows:—Carbon, 53·360; oxygen, 19·685; hydrogen, 7·021; azote, 19·934 = 100·00. The last element is found in larger proportion than in any other animal substance. Hatchett states, that there are some traces of albumen.

The colouring matter, whatever it is composed of, although the least important part of the blood, has received more attention than either the serum or the fibrin. That it is not an essential part of the nutritive fluid, is evident by its absence in many tribes of animals, and by its partial existence in the very highest. The supply of red blood, however, seems to be necessary to the exercise of the vital functions when these are performed with any degree of perfection; thus the principal part of the body of many species of fishes, receives only colourless fluids; whilst the heart, the gills, &c. are nourished by red blood. It is difficult to ascertain how the coloured parts are first formed, or of what they actually consist. Hewson contended, that each is formed of a central solid particle which is contained in a transparent vesicle. He entertained some peculiar ideas concerning the origin of these two component parts. He supposed that the vesicle was formed in the lymphatic vessels; the solid particle in the lymphatic glands; and that the red colour was produced by the action of the spleen.

Sir E. Home and Mr. Bauer, in this country, and Prevost and Dumas, on the continent, have revived this idea of the existence of a solid corpuscle being contained in an envelope. Sir E. Home has detected globules in the chyle, some of which are as large as those of the blood; he thinks that these bodies acquire their red colour by their exposure to the air in the interior of the pulmonary organs, where they are changed into the particles of the blood.

According to some recent investigations of Dr. Hodgkin, the opinions of Leeuwenhoek, Fontana, Home, and others, concerning the globular form of the red particles, are altogether erroneous. He also controverts the statements of Hewson, Home, Prevost, &c., as to the existence of the central globule and the external vesicle; nor could he perceive the separation of the colouring matter, said to take place by Home and several continental physiologists, in a few seconds after the particles have escaped from the body. Instead of being spherical, " the particles of the human blood appear to consist of flattened cakes, which, when seen singly, appear to be nearly, or quite colourless. Their edges are rounded, and being the thickest part, occasion a depression in the middle, which exists on both surfaces. This form perfectly agrees with the accurate observations of Dr. Young." " When the blood of man, or of the mammiferæ, all of which possess circular particles, is examined, considerable agitation is at first seen to take place among the particles; but as this subsides, they apply themselves to each other by their broad surfaces, and form piles or rouleaux, which often again combine amongst themselves, the end of one being attached to the side of another, producing at times very curious ramifications." I have given these extracts from the paper of Dr. Hodgkin, because it appears that his observations are extremely correct. The experiments were made with the assistance of a very powerful and perfect microscope, constructed by Mr. Lister, a gentleman who has paid considerable attention to this subject. Through the kindness of these gentlemen, I have had an opportunity of examining the human blood with this instrument, and my observation entirely confirmed that of Dr. Hodgkin, excepting that I thought a central corpuscle might be detected.

The size of the particle has been very differently estimated. It is very minute, which probably will account for the discrepancies that exist in the following measurements. The diameter, according to

Jurine, is	$\frac{1}{5240}$	part of an inch,
Ditto, in a second measurement,	$\frac{1}{1940}$	—
Bauer, without colouring matter,	$\frac{1}{1700}$	—
Bauer, with it	$\frac{1}{2000}$	—
Woolaston	$\frac{1}{5000}$	—
Young	$\frac{1}{6060}$	—
Kater	$\frac{1}{4000}$	—
Prevost and Dumas	$\frac{1}{4076}$	—
Hodgkin	$\frac{1}{3000}$	—

The size certainly varies in different animals, being largest in fishes and smallest in man and the mammalia. The magnitude does not depend on the relative bulk of the body, for, according to Leeuwenhoek, the particles are not larger in a whale than in the smallest fish.

The colour of the particles, which is red, has been attributed to various causes. It has been ascertained by Berzelius, that the particles contain a proportion of the red oxide of iron, and this substance has been, in consequence, very generally considered as the cause of the colouration. Berzelius himself, and also Brande, Prevost, and others, do not conceive that the colour of the blood depends on the iron which it contains, but on a peculiar animal dye or jelly. Whatever be the nature of the colouring matter, it is certain that the action of the atmospheric air is necessary to its production. I have often performed the experiment of exposing a portion of chyle, recently taken from a dog, to the influence of the air, and I have always seen that the chyle loses its milky appearance, and gradually assumes a rosy tint on its surface.

The specific gravity of the particles exceeds that of the other constituents of the blood; it is thus known that the former sink into the lower part of the crassamentum.

The quantity has not been very accurately ascertained; Berzelius calculated that the particles formed sixty-four parts of the crassamentum in the hundred.

The chemical properties of these bodies have occupied considerable attention, but the results are not satisfactory. Berzelius, Fourcroy, and others, thought they could detect a quantity of the red oxide of iron. Mr.

Brande detected a minute quantity of iron in the ashes of the serum and fibrin as well as in those of the red globules; but he supposed that the red tint is produced by a peculiar animal matter. Wells altogether denied the existence of iron. The question appears to be decided by Dr. Engelhart,* in favour of the opinion of Berzelius. He has detected the per oxide of iron in the proportion of a half per cent.; it is confined to the particles, its presence not being indicated either in the serum or fibrin. The colouring matter, when incinerated, leaves the 80th part of its weight of ashes, consisting, according to Berzelius, of—oxide of iron, 50·0; subphosphate of iron, 7·5; phosphate of lime, with traces of magnesia, 6·0; pure lime, 20·0; carbonic acid and loss, 16·5 = 100·0.

I have now concluded the general description of the properties of the blood. This has occupied, perhaps, more space than should have been allotted to it; but I am so strongly impressed with the conviction, that a knowledge of the circulating fluid is indispensable to every one who studies the human organization, that I have extended these observations beyond the limits which I had first proposed.

The third class of fluids, viz. those which proceed from the blood, are so numerous and diversified, that it would exceed the limits of this work to investigate each separately. This is the less necessary, because many of the humours will be afterwards considered with the structures in which they are produced. The fluids of which I am speaking, are all derived from the blood;

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* Turner, El. of Chemistry, p. 745.

the mode of separation, however, varying according to the kind of instruments by which it is effected. The term of *secretion* is applied to the process by which the fluids are detached from the blood, and these are, in consequence, often called the *secretions*. The secretory organs, different as they are in their structure and appearance, all consist essentially of the blood-vessels, which bring to them the materials for secretion, and of the peculiar canals which receive the secreted fluid. There are three species of secreting bodies. 1. Exhalent arteries. 2. Follicles. 3. Glands. In the first, the fluid exhales, or transudes from the extremities of the minute vessels. In the second, the humour is separated in a small bag or follicle. In the third, the structure is much more complicated; it is indeed so intricate, that at the present time it is but very imperfectly known. The character of the secreted fluid is influenced by the nature of its secreting organ; thus the exhalations are the simplest in their chemical properties; whilst the glandular fluids are extremely compound.

The first class is subdivided into those perspired fluids, which, having been separated from the blood, are again received into the system through the medium of the lymphatics; and into those which, on being detached from the circulating mass, are directly discharged from the body. The first are called recrementitial, the second, excrementitial, exhaled fluids.

The follicular secretions resemble each other in being formed in follicles, and in being excrementitious.

The last class of fluids are elaborated in the complicated organs, called glands. These bodies are very intricate in their structure, and the fluids which are formed by them, are also extremely compound.

The lymph is the transparent liquid which is returned to the blood by the lymphatic vessels. M. Magendie has well observed, that nothing more strongly proves the imperfection of our knowledge concerning the function of absorption, than the ideas of physiologists about the lymph. This name has been variously applied to the fibrin, and to the serum of the blood; to the fluid of the serous membranes, and to the exhalation of the cellular tissue. With the information we possess at present, it is impossible to decide, if the fluids secreted by the serous and cellular membranes are identical with the contents of the absorbent vessels. In this uncertainty, I shall restrict the name of lymph to the liquid contained in the lymphatics.

The lymph has a saltish taste, and a strong spermatic odour. It is usually transparent and colourless, but, according to Magendie, it has, when first removed from its vessels, a slight rose-colour; occasionally it presents a light yellow tinge, and at other times a red madder colour.

The specific gravity, compared to that of distilled water, is as 1022·28 to 1000·00.

When extracted from its vessels, the lymph soon congeals. Its rose-colour becomes more deep, and an immense number of irregular reddish filaments are developed, which are very analogous in appearance to the vessels spread in the tissue of the organs. When the mass of the lymph thus coagulated, is examined carefully, it is found to be composed of two parts; the one solid and forming a great many cells, in which the other remains in a liquid state. If the solid part be separated, the liquid congeals again. The former has much analogy to the crassamentum of the blood, and becomes scarlet red by the contact of oxygen gas, and purple when plunged in carbonic acid.*

The composition of the lymph must vary at different times as the absorbents take up such heterogeneous substances. The following is the analysis made by M. Chevreul; the lymph examined was that of a dog:—

Water	926·4
Fibrin	4·2
Albumen	61·0
Muriate of Soda	6·1
Carbonate of Soda	1·8
Phosphate of Lime Phosphate of Magnesia Carbonate of Lime	0·5
	1000·0

SECTION VI.

OF THE SOLIDS.

THE Solids, which constitute the basis of the body, determine its form and proportions, and impress upon it those movements which are so strongly characteristic of animal existence: they also contain and act upon the humours, so as to put them into motion. They are generally distinguished by the name of organs; but some writers have judiciously termed them instruments, on account of the actions they exercise.

The solids form but a small proportion of the entire body, when considered abstractedly. It has already been stated, that their weight is generally six, eight, or even ten times less than that of the fluids. From this it is evident, that, in every organ which may, on a slight examination, appear to be entirely solid, there is a very large proportion of fluid matter.

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* Magendie's Compen. of Phy. p. 307.

The form of the solids is extremely variable; it is generally more or less rounded, and consequently the lines are not straight, nor the angles perfect. In the greater part of the organs, the length considerably exceeds their breadth and thickness; there are but few in which the three dimensions are nearly equal. The form in which length predominates, is called the fibrous; whilst the term of laminated or membranous, applies to that in which the length and breadth are more or less of equal extent. In some organs, the particles are not arranged in any regular order, but are formed into small grains, which, united together, produce an evident granular disposition. The fibrous form is met with in many parts, for instance, in the muscles, nerves, ligaments, bones, &c. The membranous form is also frequently observed, as in the serous, mucous, and other membranes. The granular form belongs more especially to the viscera; it is very evident in the liver, in the pancreas, and so forth.

The colour of the organs is as variable as their form. Some are brown; others are red, yellow, or white. Most of them are opaque, a few only of the more delicate structures being transparent. Their degree of cohesion is extremely different; some are so soft, that it is with difficulty they can be examined; others again, are so firm and resisting, that considerable efforts are required in order to break them. Most of the solids are flexible, compressible, extensible, and elastic; some, on the contrary, are nearly, if not entirely, inextensible and incompressible.

These properties relating to the colour and cohesion of the solid organs, principally depend upon the fluids they contain. This is proved by observing the effects of desiccation; if a ligament is sufficiently dried, it becomes transparent and very elastic; whilst in its natural state, it is opaque and inelastic. Other, and equally marked changes, are produced by the loss of the fluids in the muscles, nerves, membranes, &c.

The interior arrangement presents numerous variations. Many organs are hollowed so as to form canals and reservoirs, which have external communications, such as the alimentary canal, and the urinary bladder; others form cavities, which are entirely closed; the serous and synovial membranes are of this order; others again constitute closed canals, which have ramifications; these are called vessels; lastly, some are solid or full, as the liver, the spleen, &c.

The intimate composition or texture of the solids is extremely complex in the higher classes of animals, and in man. Although this branch of anatomy has always commanded great attention, it is only within a very recent period that correct ideas have been entertained of the nature and arrangement of the organic solids. Each of these is composed of filaments and laminæ, which are interlaced with each other so as to form a kind of net-work, in the areolæ and cells of which, the humours are contained. This combination of fluid and solid parts is very intricate, and is essential to the exercise of those operations, on the continuance of which, life depends. It is necessary, in order to obtain an accurate knowledge of the structure of the body, to investigate the exact nature of these solid elements.

The ancients supposed that every solid organ might be reduced by a species of anatomical analysis, to a simple fibre, which they called the elementary fibre. They said, that this was every where of the same nature, and that it was formed of earth, oil, and iron. They also imagined, that this fibre produced what we term the cellular tissue; and that this tissue, under different degrees of condensation, formed the various organs of the body. Haller, who admitted the existence of the elementary fibre, thought that it was not visible, and that it could only be distinguished by the mind; being to the anatomist, what the line is to the geometrician. This opinion is evidently erroneous, as matter must have existence. It is equally incorrect, at least in man and in the superior animals, to imagine that the cellular tissue forms the basis of all the solids. This tissue is, undoubtedly, the most extended element in the animal organization; but it is not the only one. The best anatomists of the present day are agreed, that there are at least three, if not four, elementary fibres; viz. the cellular, the muscular, and the nervous. This division, which was suggested by Haller and adopted by Blumenbach, has been modified by Professor Chaussier,* who contends, that there is a fourth fibre, which he calls the albugineous. Many distinguished authorities, in whose opinion I concur, believe this to be merely a condensed modification of the cellular fibre.

The cellular, the muscular, and the nervous, are regarded as the elementary fibres, because we cannot, with our present means of analysis, reduce any of them to more simple structures; and because there is no living creature with which we are acquainted that presents any others in its composition. These three elementary fibres are not met with in every animal; there are many species in which nothing can be distinctly detected, except the cellular substance, and others which have only the cellular and the muscular, without the nervous fibre.

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* Table Syn. des Solides Organiques.

The cellular fibre, the most essential to organization, since it exists in every animal being, consists, according to some observers, of minute particles; while others regard it as being formed of a condensed animal substance devoid of globules, that which Meckel calls, the coagulable matter, and which we have previously described.* I have frequently examined the cellular membrane with the assistance of the microscope; the fibres which are very distinct, do not appear to be composed of globules, although globular bodies are seen at irregular distances, either singly or clustered together, but never presenting a linear arrangement. This fibre is capable of great extension, and is highly elastic. Its colour is a greyish white. It neither possesses animal sensibility nor contractility. Fourcroy, who is so celebrated for his successful researches in the department of animal chemistry, thought that the cellular substance was composed of gelatine; but we learn from the experiments of Mr. Hatchett, that it consists principally of coagulated albumen. Dr. Bostock states, however, that membranous matter also contains jelly and animal mucus.

The muscular fibre is not such an extended element as the last, as there are many animals in which no traces of it can be distinguished. It appears to consist of a delicate sheath of cellular tissue, and of a peculiar substance which is contained within it. Sir E. Home, Mr. Bauer, and others, thought they had proved that the fibre was globular; and this was generally believed till some doubts were thrown on the theory by Dr. Hodgkin, who denies the existence of particles in the muscular structure. I have made several microscopical observations upon this fibre, and I have noticed a great number of delicate lines marking it transversely, but no globules. This appearance was discovered by Dr. Hodgkin and Mr. Lister; and as they have not detected it in any other tissue, they regard it as the distinguishing feature of muscle. The fibre is soft and extensible, but it has little elasticity. The colour, which is rather variable, is in man generally reddish-brown. The property which so strongly characterizes this fibre, and concerning the nature of which there has been so much discussion among physiologists, was termed by Haller, irritability. I prefer the expression of muscular contractility, because it at once expresses the nature of the property, and cannot be confounded with any other physical or moral phenomenon. This property, which is resident in the muscular fibre, requires for its development the application of a stimulant, which may be mechanical, chemical, or vital. The analyses which have been made, shew that this fibre consists principally of fibrin.

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* See p. 25.

The nervous fibre, the least extensive of the three in its formation is somewhat similar to the last; that is to say, it consists of a sheath or tube of cellular membrane, in which is lodged the medulla or pulp, peculiar to the nervous system. Minute inspection seems to prove that there are no globules in the fibres, but a few may be seen irregularly interspersed between them. It is impossible to distinguish the exact nature of these globules. This fibre is soft and delicate, and of a whitish colour. It is distinguished from all other substances by its peculiar property of transmitting impressions to the sensorium, and of conveying the influence of volition from the brain to the voluntary muscles. It is composed of water, albumen, a peculiar fatty substance, osmazome, phosphorus, and some salts.

With respect to the albugineous fibre of Chaussier, it forms the basis of the fibrous and ligamentous textures. It is extremely resistant, and nearly, if not quite, inelastic. The colour is very white, and it has a satiny appearance. It is insensible, and possesses no contractility. The principal properties of this fibre depend on its great strength and resistance, which enable it to fulfil its office in the economy, viz. that of tying and binding parts together. Its chemical qualities are nearly the same as those of the cellular membrane.

I have already stated, that most anatomists consider this fibre to be merely a condensed modification of the cellular, and a careful examination of it proves the correctness of this opinion. In order to ascertain how far the two substances resembled each other, I placed some pieces of ligament, of fascia, and of tendon, which are all formed of the albugineous fibre, in maceration. In the course of about three months, I found that they were reduced into a soft, pulpy kind of cellular membrane, having precisely the same appearance as the latter, when that is treated in the same manner. From these and other observations, I have no doubt that the albugineous fibre ought to be enumerated as a product of the cellular, and not as an elementary structure.

Having pointed out the principal properties of the elementary fibres, I shall in the next place proceed to the consideration of the compound solids which are produced by their union and combination.

The ancients divided the organs of the body into similar and dissimilar parts. The first class consists of those organs which are similar to or resemble each other; such as the bones, the muscles, the nerves, &c. The second class is composed of the union of dissimilar parts; thus the hand is a dissimilar part, which consists of several organs, as bones, muscles, nerves, &c.: and so also with respect to the organs of the senses, of digestion, &c. This arrangement, modified and improved, has been the origin of all subsequent classifications. It has thus been of great service, and, so far as it extends, it is well founded. But it is not sufficiently minute to be of any practical use; for we find, that there are several different structures united in the same organ, which it is desirable to separate and to examine individually. For instance, in one of the similar parts, a bone; there is, first, the animal portion, which contains the earthy matter. 2. The vessels. 3. The nerves. 4. The medullary membrane and the marrow; and, lastly, there is the periosteum. In the same manner a muscle consists of the muscular fibre, of cellular tissue, of vessels, of nerves, and of tendon.

A most important modification in the mode of investigating the composition of the animal body, began to prevail soon after the middle of the last century. At this period, several writers pointed out the resemblance and connexions that exist between certain membranes and other parts, which previously had been regarded only as so many insulated and independent structures.

One of the earliest of these authors, is Andrew Bonn, who, in a thesis published in 1763, entitled "De Continuationibus Membranarum," made several important observations, the credit of which has been generally attributed to his successors, and especially to Bichat.*

Some years afterwards, the necessity of attending to the tissues of the different organs, was illustrated in an excellent paper on Inflammation, which was read by Dr. Carmichael Smyth, in the year 1788.† He states, that after a careful consideration of the various forms of inflammation, he was induced to believe that the principal causes of the specific distinctions they exhibit, depend upon the natural texture and functions of the part inflamed. He then proceeds to shew, in a most satisfactory manner, that when inflammation attacks the skin, the cellular membrane, the serous membranes, the mucous membranes, or the muscular fibres, it is in each instance distinguished by peculiar characters, and that these characters are always similar in the inflammation of the different parts which are respectively formed by the above tissues. An example of this philosophic mode of elucidating the phenomena of disease, is afforded in the inflammation of the mucous membranes, which is marked by the same leading symptoms, and has the same termination, whether it occurs in the mucous membrane of the eye, of the throat, of the bronchi, or of the alimentary canal.

This appears to have been the first attempt to arrange the symptoms of inflammation according to the tissue of the organ in which the disease occurs. About the same time, Pinel adopted nearly a similar method of distinguishing diseases according to the structure of the organic solids.*

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* Magendie, Comp. of Phy. Note by Dr. Milligan, p. 526.

† Medical Communications, vol. ii. p. 168, *et seq.*

There is, perhaps, no event in modern times, that has had so great and so beneficial an influence on the practice of medicine, as this improvement in the manner of cultivating human anatomy. It has led medical men to remark the great similarity which exists in the characters of diseases of similar textures, however distantly these may be placed from each other. It has afforded to the pathologist an incalculable advantage, in investigating the nature of disease; it has enabled him to trace the changes which are induced by it; to compare these morbid results with the healthy structure; and, lastly, to ascertain those general laws which are the only rational bases on which the practitioner can found his diagnosis and treatment. It is to the knowledge of structure which we now possess, that ought to be attributed the production of the many excellent works which have been published, within a very few years, concerning the nature and effects of disease; and to the same source, may in a great degree be referred the simplicity and success which mark the practice of medicine in the present day.

The method of studying the anatomy of the body, according to the intimate structure of its organs, has had an equally advantageous effect on zoology. The most enlightened naturalists, adopting the scientific system of M. Geoffroy St. Hilaire, no longer rest their divisions and classes on the external form, or even on the functions of the various parts of the animal economy, but upon the more essential and determined peculiarities of internal structure.

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* Nosographie Philosoph. 1788.

The ideas of Bonn, Smyth, and Pinel, were seized by Bichat, who, on this slight foundation, produced a history of the composition of the human body, which is one of the most important works that has ever appeared relative to medical science. This illustrious man, endowed with a genius worthy of the task which he undertook, devoted himself with almost unparalleled patience, to the minute investigation of our corporeal frame. Provided with means of observation, which appear almost incredible in a country where every conceivable obstacle is opposed to the practical cultivation of anatomy, Bichat sacrificed every thing to the advancement of the great work in which he was engaged. We may form some notion of his ardour and industry from the simple fact, that, in the short space of six months, he personally examined more than six hundred dead bodies.* The product of so much research was deserving of the talent and labour which had been bestowed upon it. The Anatomie Générale has been received throughout Europe as the very foundation of the branch of knowledge upon which it treats; and will remain a lasting memorial of a man, who was unhappily too soon lost to the science of which he was one of the brightest ornaments.

In the above work the organic solids are reduced to a certain number of elements, which are called *simple tissues*. A tissue is not, strictly speaking, an element, but a congeries of fibres; as it forms, however, the basis of all other parts, it may still be regarded as an anatomical element.

These tissues consist of the following:—1. The cellular; 2. The nervous of animal life; 3. The nervous of organic life; 4. The arterial; 5. The venous; 6. The exhalant; 7. The absorbent, with its glands; 8. The osseous; 9. The medullary; 10. The cartilaginous; 11. The fibrous; 12. The fibro-cartilaginous; 13. The muscular of animal life; 14. The muscular of organic life; 15. The mucous; 16. The serous; 17. The synovial; 18. The glandular; 19. The dermoid; 20. The epidermoid; 21. The pilous.* These he divided into general and particular tissues. The first are called general tissues, because they are more generally distributed than the second. Bichat also called them generating tissues, because they concur in the formation of all other parts; they consist of the cellular, the nervous of animal life, the nervous of organic life, the arterial, the venous, the exhalant, and the absorbent. The whole of these do not necessarily enter into the composition of every organ, but some of them are always observed. The cellular, the exhalant, and the absorbent systems are met with everywhere, for they are the agents of the composition and nutrition of all living beings. Arteries and veins, or at least vessels which carry red blood, are deficient in many parts, as in cartilage. The nerves are yet more confined than the blood-vessels, as there are many organs in which they cannot be traced. It must always be recollected, that these generating systems are only independent of each other in a limited degree, as there is a mutual connexion between them, each assisting in the formation of the other. For example, the cellular tissue is penetrated by vessels and nerves; the vessels contain cellular membrane and nerves, and they even receive other vessels in their parietes. Again, the nerves have cellular texture which forms sheaths for their fibres, and blood-vessels by which they are nourished.

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* Notice Historique sur Bichat, prefixed to Maingault's edition of the General Anatomy.

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* Anat. Gen. tom. i. p. 35.

The particular systems which are derived from the former, consist of the osseous; the medullary; the cartilaginous; the fibrous; the fibro-cartilaginous; the muscular of animal life; the muscular of organic life; the mucous; the serous; the synovial; the glandular; the dermoid; the epidermoid; and the pilous. The different tissues which we have enumerated, general and particular, are joined with each other in various proportions to form the solid organs of the body. Thus, a bone is an organ, composed of several tissues: of the osseous, which constitutes its substance; of the medullary, which is contained in its interior; and of the fibrous, which affords it an external envelope, under the name of periosteum; lastly, each of these tissues possesses its proper cellular membrane, vessels, and nerves.

The organs which are produced by the union of several tissues, in their turn are associated together so as to form what is termed an apparatus; the different parts of which, although their situation, structure, and even peculiar action may be very distinct, still concur in the accomplishment of one common function. Thus the teeth, the salivary glands, the stomach, the intestines, and the liver, form the apparatus of digestion.

I have given rather a detailed account of the arrangement of Bichat, because it is so excellent in itself, and also, because it is the basis on which all the more recent classifications are founded. There are, however, certain parts of it which admit of improvement, and in consequence of this, some alterations have been made by several celebrated anatomists. I shall state those which appear to be required. First, we should include under the general term of vascular tissue, the exhalant, the absorbent, the arterial, and the venous, because they are only slight modifications of the same structure. It is also necessary to add to the vascular system, a peculiar tissue, which has been long known to anatomists, although its proper character has only recently been determined; it is at present distinguished by the name of the erectile tissue. The nervous system of animal life, and the nervous system of organic life, belong to the same tissue, viz. the nervous. The medullary tissue is only a part of the adipose. The fibro-cartilaginous and fibrous organs are modifications of the same structure, viz. the fibrous. The muscular system of organic life is principally distinguished from the muscular system of animal life, by the difference in the disposition of its fibres and in the mode according to which they are excited to contract. The synovial tissue is a part of the serous; the dermoid system is a condensed variety of the cellular membrane; lastly, the pilous and epidermoid textures belong to the same class.

There is much uncertainty as to the nature of the epidermoid texture. Many anatomists regard it as an inorganic substance which is concreted on the external surface of the body. Beclard says, that it is almost inorganic, being the product of excretion, and that it ought not to be considered as an anatomical element; that it contains no distinct cellular structure; that by maceration it is reduced into a kind of mucilage, and that chemistry demonstrates in it albumen according to some, or mucus according to others. Notwithstanding this opinion, I believe that the epidermis is an organized substance, and that it is a product of the cellular texture. The reasons for this belief will be stated in the chapter on the Skin. The epidermoid tissue constitutes the epidermis, the nails, the hairs, and in animals, their horns, scales, &c. The principal character of these textures, is the great power of reproduction which they possess.

Having pointed out what appear to me to be the advantages and disadvantages of the classification of Bichat, I shall now state that which seems to be the most perfect arrangement, in an anatomical point of view, premising, however, that from the inseparable connexion of the different parts of the body, it is impossible that it should be entirely free from error.*

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* The organic solids have been variously arranged since the time of Bichat, by some of the most distinguished anatomists of Europe.

Chaussier has divided the tissues as follows:—1. Laminated or cellular. 2. Vascular, including the arteries, veins, and lymphatics. 3. Nerves. 4. Bones. 5. Cartilages, including those of ossification, of prolongation, and of articulation. 6. Muscles. 7. Ligaments. 8. Membranes, which are laminated, serous, follicular, muscular, albugineous, albuminous. 9. Glands. 10. Follicles, which are simple, congregated, compound. 11. Ganglions; nervous, lymphatic, vascular. 12. Viscera, as the sensorial, digestive, respiratory organs, &c.

M. M. Dupuytren and Magendie admit the following tissues:—1. Cellular. 2. Vascular. 3. Nervous; cerebral and ganglionic. 4. Osseous. 5. Fibrous; fibro-cartilaginous, dermoid. 6. Muscular; voluntary, involuntary. 7. Erectile. 8. Mucous. 9. Serous. 10. Horny; hairy, epidermoid. 11. Parenchymatous; glandular.

Dr. Rudolphi divides the elementary tissues into eight classes:—1. Cellular. 2. Horny. 3. Cartilaginous. 4. Osseous. 5. Tendinous. 6. Vascular. 7. Muscular. 8. Nervous. These textures form the following compound parts:—1. Vessels; divided into *general*, as arteries, veins, and absorbents; and into *particular*, as excretory ducts. 2. Membranes; *general*, serous, mucous, fibrous, dermoid, epidermoid; *particular*, as membranes of the eye, brain, and ovum. 3. Viscera. 4. Glands.

parenchyma of the whole machine. This opinion is by no means so far removed from truth, as some writers have supposed; for it is certain, that the cellular texture, under different modifications, forms nine out of the eleven tissues which I have enumerated and, it is most probable, that it also forms the sheath of the muscular and nervous fibres within which are contained the matters that are peculiar to those structures. In examining the lower animals, as the zoophytes, nothing can be detected but a substance which resembles, and which is generally admitted to be identical with, the cellular tissue.

Next in order, the tegumentary organs should be mentioned. These, which are formed of a condensation of the cellular membrane, are equally extensive with it; at least one part of them, the skin, is so; but with respect to the other portion, which consists of the mucous membranes, it is not certain if some of the infusory and other animalculæ, possess any internal cavity or stomach, and consequently any mucous membrane. The vessels are the most extensively diffused in the animal kingdom after the two preceding structures. Then succeed the muscles, the nerves, and the glands.

Lastly, the most restricted organs are the bones, the cartilages, the ligaments, and the serous membranes, which are confined to the vertebrated animals.

SECTION VII.

OF THE FUNCTIONS.

MAN, like all material beings, is endowed with certain properties which produce a most varied and complex series of phenomena, to which, in the aggregate, is applied the term of Life. Some physiologists have used this word without attaching to it a precise and definite meaning; and others have committed a more serious error, by regarding life as a principle or source of action. It is, however, certain that life is simply an effect, the efficient cause of which is beyond the limit of human investigation. Many of the erroneous opinions which have been advanced upon this subject, owe their origin to the fanciful theories of Vanhelmont, Stahl, and others, who, reviving the ideas of Hippocrates, imagined that all the phenomena exhibited in the living economy, might be referred to a peculiar principle or intelligent agent, called by some *Archeus*, and by others *Anima*. The properties upon which these phenomena really depend, are partly of a physical and partly of a vital character; the former class, as I have previously stated, comprises gravitation, repulsion, and chemical affinity; the latter, sensibility and contractility. It is not necessary to dwell upon the effects which are produced by the operations of the first class, because they are so entirely controlled and directed by the influence of the vital powers, that they are comparatively uninteresting.

The complicated actions, which are dependent on sensibility and contractility, are distinguished by the name of *functions;* a word which Richerand has appropriately defined, by the expression of *means of existence*. These functions have such a mutual influence upon each other, and are so inseparably connected together, that they form a kind of chain, which, having neither commencement nor termination, has been aptly compared to a circle. It is evident then, that every classification of the vital phenomena must be arbitrary, and, to a certain degree, imperfect.

The Ancients divided the functions into, 1. The vital. 2. The natural. 3. The animal. The first include those actions which, being immediately essential to the preservation of life, cannot be interrupted, even for a very brief interval, without causing its destruction, such as the circulation and respiration. The second class consists of those processes which, although they are not so directly concerned with the support of life, are yet indispensable to its continuance; they include digestion, absorption, nutrition, &c. The third division comprehends the phenomena which are the exclusive characteristics of animals; as the sensations, locomotion, and voice. This division has been adopted with some modifications by Haller, Blumenbach, Cuvier, Chaussier, and many others. It is particularly defective in this respect, that the processes of respiration and circulation are separated from digestion and the other actions which are subservient to nutrition. The function of generation is also confounded with the natural or nutritive functions, instead of forming a separate class.

The classification which I have adopted in my lectures, is, like the last, derived from the Ancients, the rudiments of it having been established by Aristotle. Many celebrated physiologists, as Buffon, Grimaud, Bichat, and Richerand, have modified and improved the original division of Aristotle.

The vital functions may be appropriately divided into two great classes. 1. Those which are connected with the support of the individual. 2. Those which are provided for the preservation of the species. Some of these processes are exhibited by all beings which are endowed with life; while others are restricted to the animal creation. It is for this reason that the functions of nutrition and generation are frequently termed the vegetative functions; and those of sensation and motion, the animal functions. The first are the most essential and extended; for without them the life of the individual and of the species could not be supported. The second, which are greatly developed in the human species, are not so necessary to life itself, as to its enjoyment.

The functions which preserve the individual, consist of, I. Those which accomplish his nutrition. II. Those which establish his relations with external and surrounding bodies.

I. The nutritive process in man, corresponding to the perfection of his organization, is extremely intricate, being the result of several separate functions, which all concur in producing one common end, namely, the support of the body. The processes which are subordinate to nutrition, may thus be enumerated: 1. Digestion, by which the chyle is elaborated from the food. 2. Absorption, by which the chyle is carried towards the lungs. 3. Respiration, by which certain changes are effected, so as to convert the chyle into blood. 4. Circulation, which conveys the blood into the substance of every organ of the body. 5. Secretion, by which the blood is purified, and is thus kept in a fit state for nourishment. 6. Assimilation, by which the molecules that each organ requires for the preservation of its peculiar structure, are separated from the blood.

II. The relations which exist between man and the objects that surround him, are very numerous and diversified. They depend on the perfection of his nervous and muscular systems; but more especially on those surprising faculties which constitute the human intellect.

The functions of relation consist of, 1. The external senses, which receive and convey to the percipient principle, the different impressions that external bodies are calculated to produce; they consist of the senses of vision, of hearing, of touch, of smell, and of taste.

2. Motion, which is either partial or general.

3. Voice and Speech: these powers constitute one of the great distinctions of the human race, and form an admirable medium of communication between the individuals who are endowed with them.

4. The Understanding, which controls all the operations of the economy, and bestows on man those intellectual faculties which exalt him, in an incomparable degree, above all other created beings. There appear to be four principal powers which compose the human understanding:—1. Perception, or the power of perceiving impressions. 2. Memory, or the power of recalling impressions which have been perceived. 3. Association, or the power of combining or associating impressions. 4. Judgment, or the power of perceiving the relations which exist between them.

The functions which are subservient to the preservation of the species, are modified by the phenomena of animal life; although some of the principal processes are involuntary, and proceed without the consciousness of the individual. The generative functions consist of, 1. Those which require the union of the sexes, including, *a*, the action of the male, or emission; *b*, the action of the female, or conception.

2. Those which depend on the female alone: *a*, gestation; *b*, parturition; *c*, lactation.

SECTION VIII.

OF THE DEVELOPMENT AND MODIFICATIONS OF ORGANIZATION.

THE human body, like that of all other animals, presents in the different epochs of its existence, certain modifications in its organization. Each part passes through many stages before it arrives at its maturity; so that a very considerable time is required for the perfecting of the body. This rule, which has no exception, is termed by Meckel, *law of development.*[*]

In the commencement of life, the different parts and the entire organization are more symmetrical than at a later period: thus the heart is perpendicular, and its septum corresponds to the median line; the two lobes of the liver are nearly of equal size; the stomach is vertical; the upper and the lower extremities have a great analogy with each other, &c. The resemblance which exists between the different organs, in the early period of their formation, is rendered more striking in consequence of the same general laws regulating the development of the various parts of the body. One of the most important and remarkable of these principles is, that the growth of each organ proceeds *from the circumference towards the centre*, and not, as was generally imagined until very recently, from the centre towards the circumference. It has also been ascertained, that in the commencement each organ is double, but that as the process of increase advances, the two lateral parts are joined together so as to obliterate all traces of the original division. Thus the spinal cord and the brain arise by two plates which are not even united in the origin ; the intestinal canal is formed in the same manner, consisting of two halves, which are afterwards joined in order to complete the cylinder of the gut. The same disposition is observed in the trunk of the body, and especially in the different parts of the osseous system.* The extremities of the alimentary passage and of the urinary and genital organs, appear to be confounded together, so as to form a cloaca ; and in the same manner, there is no partition between the buccal and nasal cavities.

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[*] Manuel d'Anatomie, tom. i. p. 43.

The genital organs in the two sexes resemble each other in proportion as they are examined early after conception. If any interruption occurs in the progress of development in this stage, it will give rise to the various defects called malformations, or, in some instances, to the production of monsters. It is in this manner that the hare-lip, the cleft palate, the divided perineum, the spina bifida, &c. are formed.†

The human embryo is almost entirely fluid during some days after conception. Mr. Bauer has examined the ovum on the eighth day from coition, when he found that it consisted of two membranes ; the external one open throughout its length, and the internal one containing a slimy fluid and two vesicles. At first, no globules can be detected in the organic substance ; they afterwards are perceived, but still they have no regular disposition ; at a more advanced stage, the globules are united to form fibres. By degrees, solid particles are added to the homogeneous fluid ; and thus the organs acquire density, which increases to the very termination of life. Colour, as well as consistency, is deficient in the beginning; every part being then white. In a short time, however, the circulating fluid becomes red, and gradually each part gains the colour which is proper to it.

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* Serres sur les Lois de l'Osteogenie, in Analy. des Trav. de l'Acad. des Sc. 1819.

† Geoffroy St. Hilaire, Philos. Anatomique.

The form of the various parts is more rapidly developed than the internal texture and chemical composition. The brain, for instance, has its external configuration, at a time when little or no difference can be seen between the grey and the white matter. A more decided example is furnished in the long bones of the fœtus, which possess their external figure, while they are still cartilaginous.

All the organs do not appear simultaneously, but in a successive order, which, however, it is difficult to determine in man and in the superior animals, because they pass very rapidly through the first periods of their existence. During the first month, the embryo consists of an elongated and slightly curved mass, which has one of its extremities rather enlarged, denoting the situation of the head. The extremities do not begin to appear till the commencement of the second month: at which period the vascular and the nervous systems may be perceived, and about the same time the commencement of the intestinal canal, and also of the bones, may be traced. The intestine is at first straight, but it afterwards becomes curved, and is embraced by the umbilical cord; about this time, the urinary bladder seems to be prolonged into the cord, forming the allantois and the urachus; the former of which disappears as the fœtus is developed and the cord lengthened; the urachus only remains at the time of birth, indicating the type of the original conformation.* In the fifth or sixth week after conception, a small slit representing the mouth, and two small spots or eyes may be distinguished. At the same period, the canal of the heart, filled with blood, is also perceived.† The muscles, during the first three months, present the appearance of viscous layers, with a slight yellowish tint; the involuntary muscles are first developed, and afterwards the voluntary.

The different organs are not formed as so many entire bodies, but each proceeds from insulated parts, which subsequently unite to form a whole. It has been stated above, that the trunk of the body, the nervous system, and the intestine, consist of two halves, which afterwards join on the median line. The vessels commence in isolated vesicles, which are filled with a fluid substance; these become enlarged, and are slowly converted into a ramifying canal. The kidneys are composed of several lobules, which are, in the progress of growth, confounded together. The development, by parts, is very evident in the bones, each of which has several points where the ossific process is proceeding at the same time.

The various parts of the fœtal body have not always the same proportional volume. The head, at first, is very large; and the same may be said of the abdomen; the upper extremities are larger than the lower, and the clavicle exceeds the size of the os humeri, or even of the os femoris. The relative proportion of other organs exhibits similar peculiarities.

We have already noticed the circumstance, that several parts which exist in the commencement of life, are removed afterwards. The disappearance of the membrane of the pupil, of the umbilical and other vessels, of the thymus gland, of the renal capsules, &c., is sufficient proof of the above change.

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* Notes by Dr. Copland, in Richerand's El. of Phy.

† Tiedemann, Anat. du Cerveau, par Jourdan, p. 14.

A most important and interesting fact has been determined by the investigations of Meckel. This distinguished anatomist has ascertained that "the degrees of development through which man passes from his first origin until the time of his perfect maturity, correspond to permanent formations in the series of the animal kingdom."* This resemblance is greatest according as the embryo is examined in its earliest periods. The limits of this work will not permit me to enumerate the various proofs that are brought forward to support this opinion. Professor Meckel has carefully compared the different and transient states, which are exhibited in the vascular system, in the nerves, in the sexual organs, in the osseous system, in the external form, &c. of the human embryo, with the corresponding and permanent parts of the inferior animals; and this comparison proves, that there is a great resemblance between them. M. M. Jourdan and Breschet, in a note appended to their translation of Meckel's Manual, judiciously state that it is necessary to distinguish between analogy and identity. They consider, that many modern physiologists have committed an error, by mistaking certain analogies which really exist between the organs of the human embryo and those of the lower animals, for more intimate relations.

The organization of the human body at the period of birth, is so far developed that it is capable of performing those actions which are essential to the support of its independent existence; but it is still in a very imperfect condition, and many years are required to bring it to full maturity.

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* Anat. Gen. t. i. p. 49.

The differences which are exhibited in the structure and functions of the body, have induced physiologists to divide the life of man into certain epochs, to which the name of ages has been given. These are characterized by peculiar states of the material organization and by corresponding modifications of the vital functions. The number of these periods has been variously calculated. Some of the ancients divided the life of man into seven ages, a division which is rendered familiar to English readers, by the admirable description that has been given of it by Shakspeare. Notwithstanding its adoption by our immortal poet, this classification does not appear to rest on philosophic grounds. We should rather divide the human existence into three periods:—1. The age of increase. 2. The age of maturity. 3. The age of decay. Each of these epochs is marked by the condition of the corporeal structure, and of the intellectual and other operations. I shall merely enumerate the leading facts connected with the organization in each of these periods.

The body, during the time of its growth, is in many respects imperfect. It is more fluid in proportion to its youth, so that softness of texture is the character of the first periods of existence, and rigidity of the last. Several organs, even those which are large and of great importance, are either entirely deficient in the commencement of life, or developed in a partial manner. There are examples in the bones, in the genitals, the female mammæ, the larynx, the hairs, &c. On the contrary, certain organs are formed at an early period, as the vessels, the nerves, and the liver.

The relative size of the various parts changes with growth; thus the brain, the nervous system, the heart, the vascular system, the liver, &c. have, in the commencement, a very large proportion to the rest of the body; whilst the intestinal canal, the spleen, the genital organs, the lungs, &c. continue for a considerable time in a state of relative smallness. From the combination of these circumstances, a kind of metamorphosis is effected between birth and manhood.

The age of increase is terminated about the twenty-first, or sometimes not till the twenty-fifth year, when all growth in height is at an end, and the organization is perfect. Before this period, the organs of generation, and certain parts which are influenced by them, undergo a most remarkable and sudden change. The time when this change occurs, marking the development of puberty, is greatly influenced by the climate, and by the sex and constitution of the individual. The inhabitants of warm climates are more precocious than those of colder regions. Thus, in the hottest parts of Africa, Asia, and America, girls arrive at puberty at ten, or even at nine, years of age; but in France and England, not till fourteen or fifteen: whilst in Sweden, Russia, and Denmark, the menstrual discharge is from two to three years later in its appearance.* Women attain the age of puberty one or two years sooner than men. In both sexes it may be considerably delayed, from the effects of debility and disease.

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* "The period of puberty cannot be exactly defined: it varies with climate and temperament, but is generally more early in the female; so that in our climate, girls arrive at puberty about the fifteenth year, and young men, on the contrary, about the twentieth."—*Blumenbach, El. of Phy.* p. 525. See also the Notes of Dr. Elliotson, p. 529.

The external signs of puberty are evident and decided. In the male, the organs of generation are greatly developed, and they are surrounded by hair; the voice becomes fuller, more grave and sonorous, the larynx at this period being much enlarged; the chin is now furnished with beard, and the skin losing its softness, and acquiring a deeper hue, is covered with hairs, especially in the armpits, on the anterior surface of the chest, and on the lower extremities. The whole body grows, and its individual parts begin to assume their proper proportions; the swelling of the muscles and the projections of the bones are defined, and the entire frame acquires a more determined character.

In the female, as in the male, the genitals are developed and are covered with hair; the breasts are enlarged and full: the pelvis is augmented and the hips separated; and the body becomes more full and rounded, thus giving to the form a peculiar grace and elegance. The larynx is but slightly enlarged, so that the voice still retains its softness. The skin preserves all its delicacy, and its whiteness is even increased.

The power of procreating is possessed, in our climate, by the male till the fifty-fifth or sixtieth year, whilst in the female it does not reach beyond the forty-fifth; these limits are occasionally extended. In those countries where puberty begins sooner, the capability of generating ceases at an earlier period.

The second period of human existence, or that of maturity, extends in men from the twenty-first to the sixtieth year; in women it ends at about the forty-fifth; it is obvious, however, that this is a very general calculation, to which there are numerous exceptions. In this age, the organization of the body has become perfect. The process of ossification is completed; the muscles have their firmness increased and their power augmented; and the digestive, respiratory, vascular, and nervous systems, have attained their last stage of formation. The perfection of function corresponds to that of organization, so that it is during this long interval that man enjoys the plenitude of his existence.

To the period of maturity succeeds that of old age, in which the body, losing the structure which is so admirably adapted to its mode of existence, begins to fall into decay. Its weight is diminished in consequence of the absorption of the adipose and other fluids. The skin is wrinkled and dry; the limbs become sharp and angular; the eyes are sunk in the orbit, and the cornea loses its lustre; the cheeks fall in, and the nose and chin are prominent and approach each other, in consequence of the loss of the teeth and the absorption of the alveoli. The solidity of the organs is much increased; the bones become brittle, and the muscles hard and rigid; the membranes are condensed, and the glands are often indurated; the arteries are very frequently thickened or ossified, and thus are rendered less contractile; the veins consequently become overloaded and distended with an unusual quantity of blood. Lastly, the texture of the nervous system is altered; the fibres of the brain and nerves being increased in firmness. These changes are produced by the deposition of solid and earthy substances in those structures which originally consisted of more fluid materials, till at length, the solidity of the different textures is so great, as to be incompatible with the performance of those operations on which the continuance of life depends.

This outline of the successive changes which the simple continuance of life produces in the organization of our frame, proves, that, by the natural course of events, the materials of the body are so altered as to be incapable of exercising their proper actions. This deterioration does not depend on any accidental circumstances; it is a condition of animal existence, the continuance of which inevitably causes its own dissolution.

I shall now proceed to the consideration of those modifications, which the organization of the body presents, in the two sexes. They principally, but not entirely, relate to the organs of generation. These, in the commencement of life, are not so dissimilar to each other, as they are at a more advanced period, viz. that of puberty. At this time the characters of the two sexes are strongly marked, although there is still an analogy between them. Thus the penis resembles the clitoris, the testicles may be compared with the ovaries, and even the spermatic cord with the round ligament of the uterus. So great indeed is the similarity, that the sex is ascertained with difficulty in the early period of the fœtal formation, and a slight fault in the organization, or an undue development of some of the parts, may cause a doubt as to the sex even in the adult. In addition to the differences which exist in the organs of generation, there are many others in the general form of the body, and in the proportion of its parts. Man possesses a large and robust body, which is stamped with all the attributes of strength and power; the muscles are greatly developed; the bones have large and projecting processes; the skin sets close to the parts beneath, owing to the deficiency of the cellular tissue; these circumstances conjoined, give to the masculine frame a rude but decided character. In woman, on the contrary, every part is soft and delicate. The predominance of the cellular and adipose tissues towards the surface of the body, softens down the projections of the muscles; and the absence of all osseous asperities gives to the limbs those rounded and graceful forms, which are, at the same time, the characteristic and the ornament of the sex. The female skeleton is readily distinguished by its comparative diminutiveness and lightness. The chest is shorter, but proportionally deeper than in man; the pelvis, on the contrary, is in every respect more capacious, and in all its proportions, it has evidently a relation to the functions of the organs which it contains.

The external characters appear to depend in an especial manner, on the existence and perfection of the testes in the male, and of the ovaria in the female. The ablation of these parts previous to puberty, or their original malformation or deficiency, almost entirely prevents the development of those sexual peculiarities which have been just mentioned. There are undoubtedly exceptions to this rule, but they are strictly exceptions. Castration will even, to a certain extent, produce in one sex the characters of the other: the ovaries were removed in a woman at Bartholomew's hospital; she afterwards grew thinner and more muscular; her breasts shrunk away, and she ceased to menstruate. The absence of the uterus only, does not prevent the individual from acquiring the general characters of the sex, nor does it destroy desire.

The changes produced by the imperfection of the genital organs, is still more remarkable in some birds. It was noticed by Mr. Hunter, that the female bird sometimes acquires a plumage considerably resembling that of the male, and he supposed that this metamorphosis was connected with the age of the bird, and that it only occurred when she ceased to lay. Mr. Yarrell, who has presented a paper to the Royal Society, on the change of plumage which the hen-pheasant occasionally experiences, has found that it does not depend on age, but that it is connected with some disease or imperfection of the sexual organs. He further observes, that when these organs are imperfect in either male or female, the sexes approximate so much, that it is difficult to distinguish between them.

The history of the temperaments and idiosyncracies belongs rather to the province of the physiologist than to that of the anatomist, because it is principally the functions, and especially the intellectual, that determine their characters; but as there are original modifications of the organized structures which correspond with, and probably cause, at least in part, the mental manifestations, I consider it advisable to offer a few observations on these peculiarities.

The name of temperaments is applied to certain physical and moral differences in men, depending on original peculiarities which exist in their organs, and on the comparative energy with which these exercise their functions. When these peculiarities exist in one individual only, the term of idiosyncracy is employed.

The ancients established four temperaments corresponding to the four qualities of Hippocrates—hot, cold, moist, and dry. These qualities were thought to give specific characters to the four humours, the blood, the yellow bile, the black bile, and the phlegm. According to the respective predominance of these fluids, the sanguine, the bilious or choleric, the melancholic, and the phlegmatic temperaments were founded. This doctrine continued to be followed, with some few alterations, till a very recent period; and even at this time the same terms are employed, although the principles of the humoral pathology have fallen into disrepute. It is not necessary to dwell on the modifications, which modern physiologists have introduced into the theory of the Ancients.* I shall therefore confine myself to enumerating the deviations from what is regarded the perfect organization of the body. These are, generally, but imperfectly marked, for it seldom happens that any individual exhibits, in a strong manner, the characters assigned to any temperament. In fact, it is difficult to define the state of body that accompanies some of the temperaments, because they are produced merely by the operation of the mind. In the sanguine disposition, the vascular system is developed; the body is well formed and the countenance ruddy. In the phlegmatic, the lymphatic vessels are distended; but their action, like that of the other organs, is languid; the structure of the body is relaxed, the contour rounded, and the skin pale. The muscular temperament is characterized by a predominance of the muscles, which are firm and powerfully contractile. The outline of the body is strongly marked; the head is small, the shoulders broad, and the chest capacious; the hands and the feet, and all those parts in which muscles are not placed, appear to be small. The physical characters of the bilious and melancholic temperaments, which are only modifications of the same condition, are few, and seem to depend on the undue secretion of bile. The skin is more or less tinged with its yellow colour; the hair is dark or black; the muscles are moderately developed and firm in texture; and the forms of the body harshly expressed. As regards the nervous temperament, there is no visible change in the organization, at least in the commencement; it is said that the body is emaciated, the muscles small, and the skin dry.

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* Richerand has given, in his Elements, an interesting account of the temperaments, of which he admits six, viz. the sanguine, the muscular or athletic, the bilious, the melancholic, the lymphatic, and the nervous. The melancholic and the nervous temperaments are regarded rather as resulting from disease, hereditary or acquired, than as the products of primitive and natural states of the constitution; and even it is doubtful, if the lymphatic temperament ought not to be considered as a first stage of disease. It is certain that individuals of this habit are very prone to scrofula. Dr. Bostock thinking, with truth, that the arrangement of the Ancients has a real foundation in nature, although it is encumbered with false theory, has admitted it with the addition of a fifth temperament, viz. the nervous. The following are what he terms the leading varieties of the constitution; the nervous, the sanguine, the tonic, the relaxed, and the muscular temperaments. Vol. iii. p. 310.

M. Rostan has given what he considers a more physiological history of the temperaments, founded on the predominance or inferiority of the different organic apparatuses, which carry on the most important functions of the economy. They consist of the following—1. The temperament in which the digestive apparatus predominates; this corresponds to the bilious of other divisions. 2. The temperament in which the respiratory and circulatory apparatuses predominate; this corresponds with the sanguine. 3. The temperament in which the brain and its appendages prodominate. (The nervous.) 4. The temperament in which the locomotive apparatus predominates. (The muscular.) 5. The temperament in which the genital apparatus predominates. 6. The temperament characterized by the atony of all the apparatuses. (The lymphatic.) 7. Lastly, the temperament in which all the organs and functions exhibit a perfect equilibrium. (The temperate temperament.) It has been well observed by Richerand, that this last state has perhaps never been found but in the imagination of physiologists.

In conclusion, it must be understood that, notwithstanding the accurate definitions of some physiologists and the minute characteristic details of others, there are few examples in which all the distinguishing marks of any temperament are well defined in one individual. The same person is usually bilious, sanguine, &c., and very few are influenced by one temperament alone. Even in those extreme cases, in which certain characteristics have been strongly developed in the beginning of life, the effects of climate and habits modify them in a powerful manner.

In addition to the differences of organization which are exhibited in the several temperaments, there are others of a more determined nature, which affect the internal and external appearance of the human frame. These variations are not like the preceding, confined to a certain number of individuals; on the contrary, they extend to entire nations, stamping them with peculiarities which are altered neither by time nor climate, but which have existed with precisely the same characters, in the remotest periods of which we have any historical record. These hereditary conformations have given rise to the division of the human species into *varieties*. The number of the varieties has been differently calculated by naturalists; but the arrangement of Blumenbach and that of Cuvier, are the most generally followed. I have adopted the former, which is, however, like all others, from the nature of the subject, somewhat imperfect. Blumenbach* admits five varieties: *the Caucasian, the Mongolian, the Ethiopian, the American,* and *the Malayan.*†

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* *Loc. cit.* See Notes of Dr. Elliotson, p. 552, *et seq.*

† Cuvier divides mankind into three great varieties:—the Caucasian, the Mongolian, and the Ethiopian. He states, however, that it is difficult to refer the Malays, the Papuas of the great Southern Ocean, or the Americans, to any one of these grand varieties. See *Animal Kingdom.* Translation, by Griffith, vol. i. p. 102. Richerand admits four principal races, which he calls the European Arab, the Mogul, the Negro, and the Hyperborean; the first of these divisions nearly corresponds with the Caucasian variety; and the last includes the tribes who inhabit the north of the two continents, as the Laplanders, the Ostiaks, the Samoïedes, and the Greenlanders. He thinks that the Americans ought not to be considered as a distinct râce, because it is probable that they were derived originally from the continent of

The Caucasian, or *fair variety*, is distinguished by the whiteness of the skin and the redness of the cheeks. The colour of the hair is brown, yellow, red, or black; it is generally soft, long, and abundant. The beard in the male is found in considerable quantity; the colour of it usually corresponding to that of the hair. The head possesses the form that is regarded as the most beautiful and intellectual, there being a great pre-eminence in all those characters which distinguish man from brutes. The skull, which bears a large proportion to the face, is symmetrically formed; it is smooth, large, and convex on the upper and fore parts, so that the forehead is well expanded, whilst towards the temples the cranium is slightly flattened. The face is oval, and is placed nearly vertically beneath the arch of the forehead. The features are moderately distinguished and well-proportioned to each other; the nose is narrow, convex, and often slightly aquiline; the mouth small, with the lips rather curved and expressive; the chin full and rounded. The cheek-bones are not prominent; the upper jaw and its teeth are nearly perpendicular. The Caucasian variety comprises all the European nations, except the Laplanders and the other Finnish tribes; the Western Asiatics, as far as the Obi, the Caspian Sea, and the Ganges; and the people of the north, and even some of the interior of Africa.

The Mongolian, or *yellow variety*, has the skin of a yellow colour; the hair is black, stiff, and straight; the beard, as in the dark races generally, is scanty. The

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the Old World.—*El. Phy.* by Dr. Copland, p. 531. Dr. Prichard, in his learned work on the Physical History of Mankind, has given an admirable account of every thing that relates to the characters and peculiarities of the various tribes and nations, into which the human species is divided.

head is almost square; the forehead low and slanting; the cheek-bones project outwards; the orbits are large and separated considerably from each other, having scarcely any superciliary arches; the nostrils are narrow; the superior maxilla is turned obtusely forwards; and the chin is somewhat prominent. The face is broad and flattened, and consequently the features are less distinct; the space between the eyes is broad and flat; the apertures of the eye-lids are narrow and oblique; the cheeks extend outwards, and the nose is small and flat. This great branch of mankind comprehends the remaining Asiatics, except the Malays; the Finnish races of the north of Europe; and the Esquimaux diffused over the northern parts of America, from Behring's Straits to the farthest habitable spot of Greenland.

The Ethiopian, or *black variety*. The skin is black and soft; the hair black, crisp, and curled. The head is narrow and compressed laterally, having large temporal fossæ; the forehead is narrow, very convex, and retreating; the frontal bone is shorter than in the Caucasian variety; the foramen magnum is placed more posteriorly; and the skull altogether is thick and heavy. The malar bones project forwards; the orbits are capacious; the osseous nares large, and the internal parts well developed; the jaws are lengthened forwards; the alveolar edge is narrow, elongated, and more elliptical; the upper front teeth are oblique and prominent, and the lower jaw large and strong. The face is narrow above, projecting and widened below, thus being somewhat oval, but in the opposite direction to the Caucasian; the eyes are large and prominent; the nose thick and flattened, and confounded on the sides with the projecting cheeks; the lips, especially the upper, are thick, and the chin rather receding. The fore arm and fingers are proportionally long. The pelvis is small; the legs long, and in many instances bowed; the calves are placed high; the foot is flat, and the heel projecting. This race includes all the nations of Africa, with the exception of those comprehended in the Caucasian variety; and also certain tribes dispersed in the Southern Ocean.*

The American, or *copper coloured variety*. The skin is of a red or copper colour; the hair black, stiff, straight, and sparing; the beard is almost wanting, and is often artificially removed. The cranium is usually small and light; the forehead, which is naturally short and depressed, is often greatly flattened and deformed by art; the occipital region is also flattened so that the skull has rather a conical form, the apex being above; the cheek-bones are broad, but more arched and rounded than in the Mongoles, and consequently projecting less outwards; the orbits are generally deep. The face is broad, with prominent and rounded cheeks, which give a peculiar character to the American countenance; the eyes deep; the nose is rather flat, but still prominent; every feature is distinctly marked when the face is viewed in profile. This division comprehends all the Americans, excepting the Esquimaux.

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* It is a very interesting fact, that there are many tribes of people dispersed in the numerous islands of the Southern Pacific and Indian Oceans, which bear a most striking resemblance in their physical characters to the negroes of Africa. These people, who occupy a very extensive range of countries, are distinguished collectively by the term of *Papuas*. They have generally black skin, crisp and curly hair, which is often woolly; large flat or bottled noses; thick lips and projecting jaws. Their stature is various, some of them being a tall and stout, while others are a dwarfish and ill-formed people. The negroes who inhabit the islands of the great Southern Ocean, appear to have emigrated from the central land of New Guinea, New Ireland, and New Britain, which countries are included under the name of the Continent of Papua. We are not in possession of any definite information concerning the primitive origin of the Papua tribes.

Besides the Papuas, who are characterized by black complexions and woolly hair, there are tribes of savages scattered in the Indian Archipelago and the Austral countries, who are as black as the Papuas, but have different features, and straight or lank hair. They are known by the general appellation of the Australian races. See *Prichard*, l. c. vol. i. book 4.

The Malayan, or *tawny variety*. The skin is tawny or olive-coloured; the hair black, soft, curled, thick and abundant. The head is rather narrow; the forehead slightly arched; the parietal bones above the ears, are prominent; the cheek-bones not projecting, and the upper jaw rather prominent. The face is prominent at its lower part, and not so narrow as in the Ethiopian variety; the features, viewed in profile, are more distinct; the nose is full, large, and bottled at its point. This variety includes the inhabitants of the Pacific Ocean, of the Marian, Philippine, Molucca, and Sunda Isles, and of the peninsula of Malacca.

Blumenbach regards the Caucasian division as the type or standard of the others; this, together with the Mongolian and Ethiopian forming the three most distinct varieties, while the American may be regarded as intermediate between the Caucasian and Mongolian, and the Malay between the Caucasian and the Ethiopian.

The distinctive characters which have thus been assigned by Blumenbach to the five great divisions of mankind, apply only in a general manner. We often see an European with the features of an African, and *vice versâ*. Again, although the nations which are comprehended in any variety have several points of resemblance, yet they are in many respects very different from each other; the same observation applies to individuals of the same country, of the same province, and even of the same family.

A question of great interest is connected with this subject, viz. what is the source of those characters which so strongly mark the varieties of mankind? Can they be explained by supposing that all the inhabitants of the earth have sprung from one common stock, and that the differences at present observed are merely the result of external circumstances operating on them, through a long course of ages; or, must it be admitted that there were formed, in the first creation, more than two primitive parents? It is not my intention to enter into an examination of the proofs and reasoning which have been employed respectively by the supporters of these theories, as such a detail would exceed the limits of this work. I shall only add, that the arguments adduced to support the doctrine of the origin of mankind from two common parents, are the most satisfactory, and most in accordance with the facts which are ascertained, with respect to the changes induced by external circumstances in the inferior animals.*

SECTION IX.

OF DEATH AND ITS CONSEQUENCES.

THE condition of animal, and indeed of all organized beings, is, that sooner or later their existence is terminated by *death.* Whatever might have been, in the beginning, the will of the Great Creator of the Universe, with respect to the indefinite extension of the life of man, it is evident that the present state of things required its limitation; for as we are endowed with the faculty of reproduction, the earth must have become overpopulated, if it were not for the bounds which death has fixed to the increase of our species.

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* The reader is referred for further information upon this interesting subject, to Dr. Prichard's Researches into the Physic. Hist. of Man, Bostock's El. Sys. of Phy. vol. iii. p. 286, and to Dr. Elliotson's edition of Blumenbach's Phys. p. 561.

The term of death is applied to the definite and total cessation of all those phenomena which collectively constitute the state of life.

The human body seldom reaches the limits of its existence, by the progressive and natural decay of its organization, but rather by the hurtful effects of accidental causes. So numerous and destructive are the diseases and accidents to which, at each moment of our existence, we are exposed, that not more than seventy-eight persons out of a thousand die of old age. There are then two kinds of death, natural death and accidental death.*

On Natural Death, or the Death of Old Age.†

In describing the ages of man, I have traced the principal changes which are induced in his organization by the progress of life. That outline proves that, after a certain period, the deterioration of the body is so great, as to be incompatible with the performance of those actions on which life depends. As this deterioration is inevitable, as it is the effect of the simple continuance of life, it may be truly said that even from our first creation we bear within us the germs of our dissolution. The progressive changes which take place in the structure of the body, as age increases, are attended by a corresponding decline in the energy of the animal functions. It has been said by Beclard, that life consists essentially, of the reciprocal action of the circulation of the blood and of innervation; and that the death of old age results from the simultaneous decay of these two functions, and of their respective organs. This is probably correct, but we must recollect that there are several operations which are necessary for the production and support of the above functions, the interruption of which would endanger or destroy life. It is in this manner that digestion becoming weak and slow, furnishes only a small quantity of imperfect chyle; that respiration diminished in its activity, only partially renovates the blood; and, lastly, that this fluid, no longer freed in a sufficient manner by the secretions of its noxious particles, becomes unfitted for the nourishment of the various organs. Besides these circumstances, which affect the quality of the nutritive fluid, the quantity of it is greatly diminished. The power of the heart is lessened in old age; the arteries become firmer and less elastic, and their capillary branches are much fewer than in the earlier periods of life, owing to a gradual obliteration which the injections of Ruysch and the investigations of more modern anatomists, have proved to take place to a great extent. Thus many parts which previously were pervious, are so condensed by the accumulation of solid matter, as to be impenetrable by vessels. Partly owing to these changes, partly owing to the diminution of the vital powers, independently of the physical deterioration, the functions of life are greatly debilitated, and, in part, destroyed. The nervous system loses its energy; the sensations are blunted, and even lost; the intellectual faculties are first impaired and then extinguished, and thus does the mind lapse into second childhood and mere oblivion. The muscles are altered in texture, and no longer contract with vigour; and the joints, losing their suppleness, become rigid and unyielding; the movements are weak and uncertain, the limbs totter under the body, and at length are unable to support its weight. The voice also, depending on muscular contraction, is deprived of the fulness of its tones, and becomes weak and shrill. Thus, one after another, the phenomena of animal life being extinguished, man loses the consciousness of his existence, and he is dead to all around him. But still the involuntary actions continue, although in a languid manner. Innervation, respiration, and circulation, prolong, for a short time, an inanimated existence; till at length these weakened supports yielding, life is finally extinguished. It is probable that innervation is the first that gives way; then the function of the lungs is stopped; and, lastly, the blood not being admitted through those organs, accumulates in the large veins, in the right cavities of the heart, and in the pulmonary arteries.*

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* In this place we employ the expression, natural death, in its strict meaning, and not in its more common acceptation, according to which, it is opposed to sudden or violent death.

† The reader may consult with great advantage the celebrated work of Bichat, "Recherches Physiologiques sur la Vie et la Mort." The last article of Part 1st, and the whole of Part 2d, relate to death and its consequences.

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* The right side of the heart, continuing to receive blood from the veins, beats after the cessation of the action of the left ventricle. The capillary circulation proceeds for some time subsequent to the movement of the blood through the heart. I have frequently, in repeating the experiments of Dr. W. Philip, observed the circulation in the capillaries going on for a very considerable period after death, or after the heart had been removed from the body.

Of Accidental Death.

Accidental Death, or, as it has been termed, Morbid Death, is the most usual termination of life. The causes of accidental death are too numerous and diversified to be mentioned in this place, but although they are so extremely multitudinous, the modes by which they destroy life are few. It seems to be ascertained, that any thing which interrupts the action of the nervous system on the organs of circulation, or the action of the blood on the centre of the nervous system, will cause death. It is evident that either of these events may be produced in many different ways. Mechanical and chemical injuries inflicted upon the brain, the heart, or the great arteries; upon the organs of digestion, of respiration, &c., when of sufficient severity, will destroy life. Diseases affecting the same parts, will produce a similar effect, but in a slower manner. The deprivation of air, by causing black blood to circulate in the arteries, and thus to be carried to the brain and to the coronary arteries;* and the loss of food, by preventing the formation of chyle, will cause death; but much more speedily in the first than in the second instance. Lastly, the introduction of deleterious substances into the economy, where they become mixed with the mass of the circulating fluids, proves destructive to life by the noxious influence they exert upon the vital organs.

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* Dr. Elliotson says, "when death occurs by impediment to the function of the lungs, the heart loses its irritability by its substance becoming penetrated with venous blood, and ceases to propel the blood of its cavities; and the brain becoming powerless from the same cause, ceases both to perceive uneasiness in the lungs from the want of fresh air, and to be able to will respiration. If the death of the body arise from the brain, it is by the brain being unable to continue respiration." *Blumenbach's Physiology.* Note, p. 137.

Of the Dead Body.

Life has no sooner terminated than the dead body begins to be affected by chemical agents. These speedily destroy the combinations which previously existed, and reduce the organized textures into those elementary substances which belong to all inert bodies. The process of decomposition[*] is influenced by various circumstances, which may accelerate or retard its progress, or even altogether suspend it. The state of the atmosphere, the season of the year, the age and constitution of the individual, the quantity and quality of the humours, the kind of death, &c., will, in a great degree, determine the progress of putrefaction. It is also important to state, that the mode of alteration in each organ varies according to its texture, composition, density, and actual state at the period of dissolution. The nature of the previous disease, if any has existed, will modify, in a striking manner, the phenomena of decomposition in the individual parts, and in the entire corpse.

The heat of the body is generally lowered some time before death. The process of cooling begins upon the surface and in the extremities, and afterwards extends to the trunk and internal parts, till the body is perfectly cold. This change proceeds quickly in proportion as the temperature of the atmosphere is low, as the subject is weakened by age, by disease, or by the loss of blood. Under favourable conditions, it is accomplished in two or three hours; but it commonly requires sixteen or twenty hours; or, if the weather is warm, two or three days may be necessary. During this period of cooling, the body is, in general, soft and flexible; and, having lost all resistance, readily obeys the laws of gravity, or external force.

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[*] See Chaussier. Table Synoptique des Phénomènes Cadavériques.

It is stated by Blumenbach, that the vital elasticity and fulness of parts, depend upon the contraction of the cellular tissue, and that after death, even in young subjects, full of juices, the back, loins, and buttocks, having for some time lost their vital tone, are, if the body is supine, depressed and flattened by the superincumbent weight which now is not resisted; this appearance may, therefore, be regarded among the indubitable signs of death. The eyes, which are half open, are fixed and glazed, and the pupil is dilated; the lower lip and jaw are pendent, and the mouth is partially open. The sphincters are relaxed, so that the feces and urine are occasionally discharged, and even parturition has occurred; these phenomena probably depend upon the last muscular contraction of the intestines, bladder, and uterus.

Whilst the body retains its warmth, the blood remains fluid, and, for a time, it continues to circulate, although in an imperfect manner. I have frequently observed the circulation of the small vessels of the mesentery going on upwards of an hour after life had been destroyed. The aorta and the large arteries are empty, whilst, on the contrary, the veins, the right cavities of the heart, and the pulmonary arteries are distended with black blood. It has been supposed that this depends on the elasticity of the arteries, and on the mechanism of the chest; but I believe it is principally caused by the propulsive action of the capillary vessels, which, continuing for a considerable period after the contraction of the heart has ceased, pushes on the blood towards the venous system, where it necessarily accumulates. In some instances, in which death has been caused by suffocation, this accumulation is so great as to cause congestion, erection, and even bloody transudation. The blood thus remaining fluid, obeys its gravity, and is determined to those parts which are most dependent, as the back, the shoulders, and frequently the head, causing in these places red or livid marks, which are strongly contrasted with the general paleness and yellowness of the body.

It sometimes happens that the face looks flushed, a deceitful appearance, which was thought by the late Mr. Chevalier, to depend on the oxygenation of the blood which had stagnated in the cutaneous vessels.

The contractility of the muscles may be excited for some hours after death; but the period varies in different animals, and even in the different muscles of the same animal.

In proportion as the animal heat is lost, the soft parts gradually stiffen, and the muscles contract and become rigid. The blood, which, till this period, had remained fluid, now coagulates, and forms in the vessels yellowish concretions, which are often intermixed with soft black coagula; it frequently happens, however, that the blood has the dark venous character.* In consequence of these changes, the limbs are rendered stiff and resisting, and the articulations are immoveable, unless considerable force is employed to bend them. The stiffness of the dead body begins in the trunk, and extends to the upper and then to the lower extremities.

This phenomenon, which is almost constant, exhibits many varieties as to the time of its commencement, its intensity, and duration. In sudden death, caused by violent affections of the brain and nervous system, the cadaverous contraction does not take place, the muscles remaining flaccid, and the blood fluid. In such cases, the warmth of the body is maintained for a considerable period. In the death of age, in that caused by chronic disease, by phthisis, by excessive fatigue, by septic, gangrenous, or scorbutic diseases, the stiffness, which follows very quickly, is not intense, and continues only for a few hours. On the contrary, in young, strong, or robust persons, in those who die from violence, from suffocation, or from acute diseases, the stiffening does not commence for twenty or thirty hours, it is very great, and remains during three or four days.

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* There is occasionally observed in the ventricles, an appearance which has been mistaken for polypi of the heart. This is owing to the fibrin of the blood being firmly coagulated in the meshes of the carneæ columnæ.

The rigidity of the soft parts ceases spontaneously, and in the same order in which it began. It is succeeded by an universal relaxation and softness, which gradually augment. The humours which were coagulated, again become fluid, and their fluidity is even increased. They gravitate into the dependent parts, and produce a general flabbiness of the corpse. The limbs are abandoned to their weight, and directed by it, they readily bend of themselves. These are the first phenomena of putrid decomposition. Some anatomists have observed, that the hair and the beard continue to grow for some time after death. This has been doubted, but it is a fact that I have had frequent opportunities of witnessing in the bodies which are brought into the dissecting room.

Putrefaction is an intestinal and spontaneous movement, the inverse of the organic action, which is established in a body totally deprived of life; which separates the particles of the organic textures; reduces them into a more simple state of composition, and finally converts them into gas, into pulp, into earth, and so returns their elements to the general mass of inert bodies. When putrefaction has commenced, the corpse exhales an unpleasant odour, which becomes more nauseous as the process advances. In general, and particularly after violent or sudden death, a considerable disengagement of gas occurs, in the intestines, in the stomach, in the cellular tissue, in the serous membranes, and often in the vessels, especially in the veins. This evolution of gaseous matter causes many phenomena. Thus the tympanitis of the abdomen, by pushing up the diaphragm, frequently causes the frothy mucus of the lungs to pass out by the mouth or nostrils; and by compressing the stomach, it forces its contents into the œsophagus and pharynx, and from thence they pass into the larynx, or into the nose and mouth. The blood and other fluids are also crowded to the head and neck, producing the hideous bloating of the countenance and starting of the eyes, which are so often the accompaniments of decomposition. The distension of the abdomen is sometimes so great as even to cause rupture of its parietes. The generation of gas in the cellular tissue, constitutes cadaverous emphysema; and its accumulation in the heart and vessels determines the movement of the blood, and even its exit through any wounds which may exist.

The chief products to which the dissolution of the animal body gives rise, are water, ammonia, carbonic acid, and sulphuretted, phosphuretted, and carburetted hydrogen gases.*

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* Turner's El. of Chemistry, p. 789.

During life, the various humours are retained in the vessels by the density of their membranous parietes; but after death, these losing their tone, allow the transudation of their contents, which then impregnate with their colour and odour the surrounding parts. Thus the blood, escaping into the cellular membrane, allows the course of the large veins, and occasionally of the smaller branches, to be traced upon the surface of the body by so many dark or greenish streaks. In the same manner the bile of the gall-bladder tinges the duodenum and other parts; and the stomach is often marked by the liver and spleen. The cellular tissue and serous membranes are infiltrated by a sero-sanguineous fluid, giving to those parts a reddish or brownish colour; whilst the walls of the abdomen are of a blueish or greenish hue. The redness which is caused after death by the transudation of blood, is very liable to be mistaken for inflammation. This fact should be impressed on the mind of every medical man, on account of its importance both in pathology and medical jurisprudence.* The humours of the eye become opake, and, transuding, produce relaxation of the cornea.

As putrefaction advances, the epidermis is raised in several places by a brownish sanies, and may be readily stripped off; when the cutis is thus exposed, it is at first whitish, moist, and soft; but it soon becomes dry, hard, and discoloured, by the evaporation of its fluids.

The muscles, imbued with fluids, become moist and soft; their colour is changed to a dark red, and afterwards to green; their fibrous structure is lost, and they are converted into a pulpy and putrid mass.

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* See an interesting paper upon this subject, by Dr. J. Davy, Med. Chir. Trans. vol. x. p. 89. Also, Chaussier, l. c.

Lastly, the texture everywhere disappears; the soft parts, confounded with the fluids, are reduced to putrelage of a semi-fluid nature; this is mixed with bubbles of gas, and spreads a most noxious odour. The bones, exposed and naked, yield in turn to the action of chemical agents; they become friable, and at length are converted into a small quantity of earthy substance, the only remains of that structure, which a short time before had excited such admiration, by the beauty of its form and the perfection of its organization.

The process of decomposition varies greatly as to the period of its commencement and completion. It requires, as necessary conditions for its development, the contact of air and a certain degree of heat and of moisture. When these conditions are favourable, particularly after certain diseases, putrefaction commences almost at the moment of death, and passes through its stages with great rapidity. In the contrary cases, it is slow, and may only be completed after many years; or even it may be almost indefinitely suspended. Thus, if a body be kept in a very low temperature, putrefaction does not occur, so that the corpse may be preserved with little alteration, whilst congelation remains. Again, if a body be dried by a very hot and dry atmosphere, as that of the deserts of Africa, or by an absorbent earth, as in certain caverns, it may become almost imputrescible. Decomposition may also be prevented by certain substances which are termed antiseptic, such as camphor, resins, bitumen, acids, neutral salts, alcohol, &c.

Putrefaction usually begins in the abdomen, in consequence of the quantity of excrementitious matter which it contains. It speedily attacks those organs which are naturally soft and have a large proportion of fluids, such as the brain and spinal cord. The structures which are deteriorated by disease, or are congested with liquids, are also among the first parts which are changed. The fibrous organs resist longer than any others, except the bones, which are the last to yield.

Putrefaction is the process by which organized bodies deprived of life, are decomposed, and by which the particles previously combined by vital affinity, are disunited and ultimately restored to the general mass of matter, where they are again employed in the formation of new beings.

CHAPTER FIRST.

OF THE CELLULAR AND ADIPOSE TISSUES.

THE observations which are contained in the preceding introduction, concerning the general structure of the human body, prove that the cellular membrane is the most extensive and important of all the tissues. The description of this essential element of organization ought, therefore, to precede the consideration of the other parts of the animal frame.

This substance is usually distinguished by the name of cellular tissue or texture, and as this name expresses one of its principal characters, we may still employ it. Many other terms have been used by different writers, such as mucous, gelatinous, reticulated, filamentous tissue, &c. The adipose tissue is usually comprehended under the general denomination of cellular membrane. But this arrangement has been properly objected to, on account of the distinction that exists between the cells which lodge the fat and those which contain the common serous fluid of the cellular substance. In consequence of this difference, although I have arranged the cellular and adipose membranes in the same chapter, on account of their general resemblance to each other, I shall describe each tissue separately.

PART FIRST.

OF THE CELLULAR TISSUE.

THE structure and arrangement of this important tissue, have been carefully investigated by many anatomists; but we are particularly indebted to Haller for the discovery of several interesting facts concerning its properties. He proved, by minute and accurate dissection, that it is uninterruptedly continued all over the body, and that in this manner it constitutes the common bond of union between the different regions and organs. It also enters very largely into the composition of all the organic solids, many of which are, in fact, entirely formed of the cellular substance, variously modified and disposed.

The cellular membrane may be divided, according to its arrangement, into two parts; the first of these fills up the interstices which are left between the various organs, and thus unites them with each other; the second portion closely surrounds the organs, and also penetrates into their interior, so as to contribute largely to their formation. This division, although very useful, does not, in strict language, exist; because it has been determined, as we have just stated, that all parts of this tissue are continuous with each other.

SECTION I.

OF THE COMMON CELLULAR MEMBRANE.

THE first division of the cellular tissue is called, on account of its disposition, the common or external portion, *textus cellularis intermedius vel laxus*. It has the general extent and form of the body, constituting, as it were, the mould of its individual parts. With the abovementioned reservation, it may be considered as a separate system, there being fewer connexions in the different regions between it and the internal division or portion, than there are between its own individual parts.

The quantity of the general cellular texture is not the same in all parts. It is accumulated in those places where there is extensive motion, and also around most of the internal organs.* It is in larger proportion on the anterior, than on the posterior part of the trunk, because the body moves more freely forwards than backwards. For the same reason this structure abounds on the face, especially about the eyes and cheeks; and likewise on the fore part of the neck. In the limbs, it is met with in considerable quantity in the flexures of the joints, in the axilla, on the elbow, the wrist, and in the palm of the hand; also in the groin, behind the knee, before the ankle, and in the sole of the foot. The superficial muscles, which produce great motion, are separated by thicker layers of membrane than the deeper seated and more fixed.

In the great cavities of the body the cellular tissue surrounds the viscera. In the abdomen it envelopes the liver, pancreas, and kidneys; and in the pelvis, the organs of urine and of generation. It also occupies the space which is included between the numerous folds of the serous membranes; thus it is accumulated in the mesentery, in the omenta, in the anterior and posterior mediastina, &c.

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* Dr. W. Hunter, Med. Obs. and Inq. vol. ii. p. 30.

There is an universal communication between the different parts of the cellular tissue; this is most evident in the neighbourhood of the large openings of the body, in the voids which are left between the various organs, and in the course of the great vessels. Thus the membrane of the neck is continuous with that of the chest, in the space behind the sternum, and on the sides, it joins with that of the upper extremities under the clavicles, and around the subclavian vessels. Again, the cellular texture of the thorax is continuous with the same structure in the abdomen, through the openings of the diaphragm, on the sides of the aorta, of the œsophagus and of the inferior vena cava. In like manner, the tissue of the abdomen is joined to that of the lower limbs, under the crural arches, through the ischiatic notches and obturator foramina. In the different regions of the extremities, and on the exterior of the trunk, the uninterrupted communication of the cellular substance is readily demonstrated with the scalpel, or by inflation.

The density of the different parts of the general cellular tissue is subject to great variation; for example, in the palm of the hand or sole of the foot, it is firmer and closer in its texture, than it is around the kidneys, or in the scrotum. In some situations, the membrane is so much condensed, that it constitutes certain structures, which have been termed fasciæ. We find, that, under the skin of the abdomen, it forms the fascia superficialis; in the perineum, the fascia perinei; and on the side of the neck, the fascia cervicis. It is most probable that the fasciæ, properly so called, as the fascia of the fore-arm, and the broad fascia of the thigh, are also only condensed specimens of the same structure.

SECTION II.

OF THE SPECIAL CELLULAR MEMBRANE.

THE second division of the cellular tissue is called the special or internal, because it immediately surrounds the organs and enters into their structure. It admits of a subdivision into two parts: the first investing the different organs, is named the *textus cellularis strictus;* and the second, penetrating into their interior, is called the *textus cellularis stipatus.*

The first portion, which surrounds each organ so as to separate it from the neighbouring parts, is, on the one hand, insensibly continuous with the general cellular tissue, and on the other, with that entering into the organs. The observation of many diseases proves that this separation often limits the extent of the morbid action. Thus inflammation attacking the tunica vaginalis, is often restricted to that membrane, and does not implicate the body of the testicle. The conjunctiva scleroticæ is frequently inflamed, while the sclerotic itself is unaffected. Again, vessels and nerves are occasionally healthy when they are surrounded with pus. But we must not attribute these limitations to the disposition of the cellular membrane alone, as the differences in the texture, and especially in the function of the above parts, have considerable influence in regulating the extent of the diseased action. We cannot therefore entirely agree with Bordeu, or with Bichat, who adopted the same opinion, that the cellular substance forms a species of atmosphere around the organs, which confines their natural actions and morbid phenomena.*

The connexion which exists between the investing cellular membrane and the different organs, exhibits many peculiarities. The solid parts, as the liver, the pancreas, and the glands generally, together with the muscles and the nerves, are entirely surrounded by membranous envelopes. On the contrary, the skin, the mucous and the serous membranes, having one face free or unattached, are only connected on one side with the cellular tissue, which is distinguished according to its situation, by the terms of the subcutaneous, the subserous, and the submucous cellular tissue. The submucous tissue of the alimentary canal is frequently called the nervous coat. An objection has been properly urged by Meckel, against the comparison that has been made between the skin and the mucous and serous membranes in the above respect. The latter are, in fact, hollow organs, enveloped on all sides;

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* M. Portal contends, in opposition to the doctrine of Bichat and others, that inflammation of the different membranes, as of the pleura, pericardium, and peritoneum, very seldom occurs without the contained viscera *participating in the disease*. See Mémoires sur la Nature et le Traitement de plusieurs Maladies. It is necessary to state, in justice to Bichat, that he distinctly says, inflammation may be, and often is, propagated by the cellular membrane, from the pleura to the lungs, from the pericardium to the heart, and from the peritoneum to the intestines.—*Anat. Gen.* tom. i. p. 77.

whilst the skin is only covered on one surface, viz. its internal.

The vessels and canals of the body are possessed of particular cellular layers; these equally exist in the arteries, veins, lymphatics, and excretory tubes.

The density of the investing cellular substance is not the same in all the regions of the body. It is condensed in the whole length of the median line, except in the neck.* It also contracts close connexions to the parts beneath, wherever the skin is fixed, as at the wrist, at the ends of the fingers, on the scalp, &c. On the contrary, it is lax in those places in which the integument is loosely attached, as in the eyelids, cheeks, scrotum, &c.

The last part of the cellular tissue, or that which penetrates into the organs, has received great attention, in consequence of its importance in the construction of the animal frame. It not only enters into the various organs of the body, but, with the exception of the muscles and the nerves, it also forms their basis. As we have explained in the introduction the relations which exist between the cellular and the other textures, it is not necessary to dwell on them in this place. It is sufficient to state, that it forms the mucous, serous, and fibrous membranes; that it constitutes the tunics of the vascular system, with the exception perhaps, of the middle coat; that under the name of parenchymatous substance, it forms a large part of the secreting and absorbing glands, not only surrounding the lobes of the former organs, but also their lobules and minute granules; and lastly, that it invests the fasciculi, fibres, and most delicate filaments of the muscles, and the cords and fibrillæ of the nerves.

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* Bordeu, Recherches sur le Tissu Muqueux, p. 66.

The different organs are provided with this important substance in various proportions, the quantity, however, is generally determined by the number of constituent parts and by the peculiar structure, which each organ possesses. A striking contrast is offered in this respect, by comparing the muscles, the nerves, and the glands, in which the cellular tissue abounds, with the tendons, the cartilages, and the bones, in which it exists in so small a proportion, that it is perceived with difficulty.

The density depends principally on the size and degree of exposure of the parts, where it is examined. The cellular membrane becomes finer as it divides and sub-divides, in order to include the more delicate parts of the organs; thus the tissue which encloses the muscular fasciculus, is coarser than the sheath which is afforded to the fibre or filament; and again, the membrane which belongs to one of the exposed nerves of the extremity, is firmer and more condensed than the soft production that penetrates into the substance of the portio mollis.

SECTION III.

ORGANIZATION OF THE CELLULAR TISSUE.

HAVING considered the general disposition of the cellular tissue, I shall now proceed to inquire into the mechanical arrangement of its different parts, and into its internal composition. On these points there is much discrepancy in the opinions of anatomists. Those of

France and of this country, almost exclusively adopt the idea of Haller; while in Germany, the theory of Bordeu is more generally received.

Haller considered that the cellular tissue consisted of numerous fibres and of laminæ or plates, crossing each other in every possible direction, and thus intercepting small spaces or cells, the size and form of which are very irregular. Bordeu says, that it is a viscous, homogeneous, and coherent substance, scarcely solid, and devoid of form; he also compares it to the jelly of meat, and to thick saliva, or foam "*bave*." His opinion has received the support of Blumenbach, Rudolphi, Meckel, &c. The last states, that in the inferior animals, and in the embryo of the human and all other species, the cellular, or, as he terms it, the mucous tissue, has the conformation described by Bordeu. He continues, "we can convince ourselves of the exactness of this in all the epochs of life. With the naked eye, or with the aid of the microscope, we see neither laminæ, fibres, nor cells; we perceive nothing but the above substance, having no openings in it. The only cause of this substance appearing to be composed of fibres and layers, is, that its viscid character allows it to take those forms when it is drawn out or extended, and nothing is more easy than to see, with or without the microscope, these layers and fibres produced under the very eyes of the observer. When, for example, we separate from each other two muscles or two fasciculi, the homogeneous substance which is placed between them, appears at first unequal and furrowed, partly retaining its cohesion; but if we continue to draw it out, it tears and produces filaments or small cylindrical columns, which acquire greater length as we increase the extension. Ceasing this extension, the filaments at first contract, and afterwards unite again into a mass, of which all the parts are blended together."* This celebrated anatomist also contends that the appearance of cells is owing to the circumstance of the air entering into the mucous tissue, when it is artificially extended; in proof of which, he states, that on ceasing the distension, the air escapes and the cells disappear; that on repeating the experiment the cells are again formed, but greatly differing from those first observed, both as to size and figure.

Bichat† gives an account, which is very similar to that of Haller. He says that the cellular texture consists of an assemblage of filaments, and of whitish layers, which are soft, and are interlaced in all directions, so as to form a thin and semi-transparent web, which has a great number of interstices or cells communicating together. These cells vary in size; they are particularly capacious in the eyelids and scrotum; but as they admit of contraction and dilatation, nothing positive can be ascertained in this respect. The figure of the cells is also so various, that it cannot be accurately described. If a limb, which is infiltrated, be frozen, a thousand small icicles will be formed, assuming the shape of the containing cells; some of them are circular, others cylindrical, &c.

From the examinations which I have made of the cellular membrane, both with the naked eye and with the aid of an excellent microscope, I am induced to believe, that it consists of an immense number of fibres which cross each other in every possible direction, and thus intercept very irregular spaces. I have not been able to detect any *linear arrangement* of globules, although rounded corpuscles may be seen at irregular distances, which are in some places clustered together, and in others dispersed in an isolated manner. It is difficult to determine whether these globules consist of solid matter, or merely of an animal fluid. When the cellular tissue is viewed through the microscope, nothing but fibres can be seen; so that it appears the layers, which are apparent to the naked eye, consist merely of fibres joined together.

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* Manuel d'Anat. tom. i. p. 104.

† Anat. Gen. tom. i. p. 66, *et seq.*

The cells, which have no determined form or size, communicate with each other. Among the many proofs which might be adduced in support of this position, the most decisive is the general diffusion of air and fluids when they have been extravasated. Thus in emphysema, the whole of the body has been seen enormously distended with the air which has escaped from the wound of the lung.* In a similar manner, butchers inflate animals, by making a puncture in some part where the tissue is lax, and from that one aperture the air is forced to the most distant parts of the body. In anasarca the fluid gravitates to the most depending situation; and in slighter affections, induced by general debility, any effusion which happens, is seen in the legs, especially about the ankles. Again, in rupture of the bladder or urethra, the urine is extravasated in the perineum, scrotum, penis, and even thighs. Those who deny the fibrous and cellular structure of this tissue, refer the above phenomena to the permeability which it possesses, owing to its soft consistence.

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* A very remarkable case of emphysema is related by Dr. W. Hunter, Med. Obs. and Inq. vol. ii. p. 17, *et seq.*

The intimate nature of the cellular tissue has been investigated by many distinguished anatomists, and, as in all other questions relating to the minute structure of the animal body, these enquiries have given rise to many contradictory theories.

It was supposed by Ruysch, that this tissue is entirely vascular, and, more recently, Mascagni has said, that it consists of white vessels; it is not necessary to dwell on these hypotheses, because, in the present day, their fallacy is universally acknowledged.

The deservedly high reputation of Haller requires that we should maturely reflect on all that he has advanced, and reject nothing until it has been proved ill-founded. This admirable physiologist refuted the doctrine of Boerhaave, according to which it was assumed, that all parts of the body are formed of series of vessels possessing different calibres. But, as it has been judiciously remarked by Dr. Bostock, in accomplishing this object, Haller probably went too far into the opposite extreme; for he is disposed to regard some of the ultimate parts of which the solids are composed, as unorganized. This opinion he seems to have adopted, partly from an idea that a vascular structure is essential to organization, and, partly, because, in the division of the larger fibres into those which are more minute, we must at length arrive at a fibre which is too small to admit of further subdivision. The idea that vascularity is essential to organization, or, in other words, that where there is no circulation there can be no organization, has been adopted by Dr. Hunter and most other modern physiologists. The researches, however, that have been made concerning the composition of the lower animals, prove that organized structures exist in which it is impossible to trace any vessels. The microscopical examination of the elementary substances in man, and in the more perfect species of the brute creation, also seems to shew, that the ultimate fibres are composed of solid matter which is beyond the limit of vascularity. The whole of the obscurity in which this question is involved, appears to hinge upon the difficulty, if not the impossibility, of determining the exact nature of the communication that exists, between the minute capillary vessels and the peculiar substance which belongs to each organic solid.

This tissue is in reality composed of the elementary cellular fibre, which has been previously described.* It is semi-transparent and colourless when seen in thin slices; but it becomes whitish or greyish, when it is examined in thicker masses. Meckel says, the white colour does not properly belong to this tissue. It depends, according to him, on the reflection which the light experiences from an infinity of surfaces, when the formation of a great number of layers and filaments has been caused by artificial means.

In regarding the vessels of the cellular structure, it is necessary carefully to distinguish those which merely pass through it, from those which are properly distributed to its substance. Some of the former are of considerable calibre, as, for instance, those which traverse the subcutaneous tissue in order to reach the skin. There is considerable difference of opinion among anatomists with respect to the existence of exhalants and absorbents in the cellular membrane. Many writers have described such vessels, although it is very difficult to demonstrate them, in consequence of their minuteness. It is, however, stated by Bichat, that in a living animal, numerous branches may be perceived arising from the large arteries which traverse the cellular tissue, and which branches are distributed to its substance. He also says, that the exhalants may be rendered manifest by artificial injection.

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* See p. 59.

The absorbing vessels, according to the same authority, correspond to the minute arteries, although they cannot be traced by the eye, nor filled by injection.

This account has been recently called in question, especially by Magendie[*] and Fodéra.[†] These distinguished experimenters, returning to former doctrines, conceive that the phenomena of exhalation and absorption depend principally on the mechanical operation of transudation and imbibition. As I shall have occasion again to allude to these opinions, I shall merely state in this place, that they appear to be satisfactorily substantiated by numerous experiments.

We may observe, in conclusion, that although the researches of M. M. Magendie and Fodéra, tend to disprove the existence of exhaling and absorbing vessels with open mouths or lateral pores, as they have been described by former writers, there is no evidence to shew that the cellular tissue does not possess, like the other parts of the body, proper arteries and lymphatics for the conveyance of the secreted and absorbed fluids.

It is difficult to determine if any nerves are distributed to this structure; for although many nervous branches pass through it to other textures, no filaments can be traced into the cellular membrane ; it may also be stated, as another indication of the absence of nerves, that this tissue is, in its healthy state, insensible. I am inclined, however, to believe, that there is a communication with the sensorial organ, because pain is experienced in inflammation of the cellular substance.

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[*] Compend. of Phy. p. 350, *et seq*, and p. 447, *et seq*.

[†] Journ. de Physiol. tom. iii. p. 35, *et seq*.

SECTION IV.

CHEMICAL COMPOSITION.

THE chemical composition of this substance has been frequently examined, but it is only within a comparatively recent period, that correct ideas have been entertained respecting it. Thus Haller thought, that the cellular fibre was formed of earthy particles, which are held together by an intermediate glue or cement, composed of oil combined with water.

The discoveries of modern chemistry have disproved this theory, by shewing that earth is not such an essential constituent of membrane as was formerly supposed, and also that the particles which compose the cellular tissue, or any other solid, are held together by a vital attraction, and not by any particular connecting medium. We are indebted to the French chemists for more correct information concerning the nature of the animal compounds. Fourcroy, finding that a large quantity of jelly could be extracted by boiling from many membranous bodies, was disposed to regard membrane as essentially composed of jelly. He states, that the cellular texture, and other parts which resemble it in their chemical composition, as tendons, ligaments, &c. are entirely dissolved in boiling water, and form with it, while it remains hot, a viscous fluid, which, when cold, concretes into a transparent and tremulous jelly. This statement is erroneous in two respects; in the first place, there is probably no single article of these enumerated by Fourcroy, which is completely soluble in water when boiling under the ordinary atmospheric pressure; and, secondly, although jelly, in a greater or less proportion, may probably be procured from all of them, yet they differ very much in the quantity which they contain.* We learn, from the experiments of Mr. Hatchett, that condensed or coagulated albumen, forms the basis of membranous matter; but it also probably contains some jelly, especially in young animals in which this substance forms so large a proportion of the body. Another substance, according to Dr. Bostock, enters into the constitution of membrane, or at least is frequently connected with it, viz. animal mucus. This appears to be nearly related to albumen, and is probably a mere modification of it.

A large quantity of water is contained, as in all other parts, in the cellular tissue. When deprived of this by desiccation, the texture loses some of its physical properties, and acquires new ones. According to Bichat, it remains white; the cells adhere together, and the laminæ, which were spread out for the purpose of drying, have the appearance of a serous membrane. When it is again placed in water, it regains, although in an imperfect manner, its former aspect. Exposed to a red heat, it dries rapidly, becomes crisp, and ends by burning.

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* Bostock, El. Sys. of Phy. vol. i. p. 46.

It resists putrefaction for a long period, so that it requires to be kept for months in water before decomposition is effected. It is at length converted into a viscous substance resembling mucilage. This resistance to decomposing agents, appears, in part at least, to depend on the degree of density which the membrane possesses; thus ligaments remain unchanged longer than the common cellular tissue.

Membranous matter is soluble in the mineral acids, with the assistance of heat. It is also dissolved in the pure fixed alkalis. With respect to the ultimate chemical elements, it seems that the cellular tissue consists of oxygen, hydrogen, carbon, and azote. The last named substance is found in a smaller proportion than in some other animal bodies, and it is probably owing to this circumstance, that membrane is capable of resisting for so long a time, the influence of putrefaction.

SECTION V.

PROPERTIES AND FUNCTIONS.

THE properties and uses of the cellular tissue are of great importance, in consequence of the influence they exert on the actions of the other organs of the body. The physical qualities, such as cohesion, flexibility, extensibility, and elasticity, are much more strongly marked than the vital ones of contractility and sensibility; indeed there is reason to doubt if the two latter are ever developed in the cellular substance, at least while it continues in a state of health. The cohesiveness of this structure, which is one of its essential properties, varies according to the nature and situation of the organs with which it is connected; thus, in some places, its cohesion scarcely exceeds that of a viscid fluid, while in other parts its resistance is so great that it cannot be overcome, except by considerable force.

Flexibility and a certain degree of extensibility are also necessary; for if the cellular membrane was unyielding, the movements of the body could not be performed, or only at the expense of great muscular exertion.

The elasticity of membranous matter is decidedly its most important property, as we may refer to it all those phenomena which have been supposed by some writers, especially by Bichat, to result from contractility. This celebrated physiologist ascribes the contraction of the scrotum on exposure to cold, to the contractility of its cellular structure, and although he says that this contraction is not to be compared to that of the muscles, yet, he conceives, that the two operations differ from each other in degree only, and not in kind. The preceding phenomenon may be more correctly explained by supposing that the cremaster is the principal cause of it, and that the application of cold, by corrugating the scrotum, assists in producing the appearance that has been noticed.

Blumenbach describes the contractility which is observed in membrane, after it has been over distended, by the name of *vis cellulosa;* this term, however, does not imply the same kind of contraction as that of the muscles. He adduces, as an example of the vis cellulosa, the action of the cellular membrane in propelling the serous exhalation into the lymphatic vessels. Bichat has also attributed to the same kind of power, which he calls *insensible organic contractility*, the exhalation and absorption of the cellular texture. It is probable, that all the phenomena which have been brought forward by the above physiologists in support of their opinions, may be accounted for by the elastic property which is so greatly developed in this structure, and by its power of imbibition.

The question concerning the sensibility of membrane, has given rise to much discussion among anatomists. It has been judiciously remarked by Haller, that many of the errors which have prevailed upon this subject, have been caused by the most distinguished authors confounding together under the same denomination, the nerves, the tendons, and the ligaments. This erroneous opinion was derived from Hippocrates, who decided, that tendinous and membranous parts are among the most sensible organs of the body.

We may conclude from the investigations of Haller, Whytt, and others, that the cellular texture in its natural condition, is insensible; but that when it is inflamed, it becomes extremely painful. In the latter state it is difficult to determine, whether the pain should be referred to the sensibility of the cellular tissue, or, to the distension of the nervous branches which traverse it, in order to reach the surrounding structures.

The cellular tissue is the seat of a very active process of secretion and absorption. In health, these two operations are equal to each other, so that no accumulation occurs; but as soon as the equilibrium is destroyed, the fluids distend the cells and gravitate to the most depending parts. The secreted liquid which has a great resemblance to that derived from the serous membranes, appears to fulfil a similar office in the animal economy; that is to say, it facilitates the motions of the various organs, in consequence of lubricating the delicate fibres of the cellular tissue.

I have alluded, in another part of this chapter, to the opposite opinions that prevail with respect to the mechanism by which these processes are effected. Until very lately, anatomists believed, that secretion was accomplished by certain minute arteries called exhalants, and absorption, by the agency of the lymphatic vessels. The experiments that have been performed by M. M. Magendie and Fodéra, tend to disprove the existence of these exhaling and inhaling tubes. The latter of these physiologists draws the following conclusions from his investigations: 1. That exhalation and absorption are respectively effected by transudation and imbibition, and depend on the capillarity of the tissues. 2. That this double phenomenon may take place in all parts of the body, and that the liquids with which they are imbibed, may be equally carried by the lymphatic vessels, or by the arteries and veins.* The experiments by which these opinions are supported, merit great attention, in consequence of their importance; but although they have determined many new and interesting facts, the question concerning the exact mechanism of exhalation and absorption, must still be considered as veiled in obscurity.

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* Jour. de Physiol. tom. iii. p. 41.

PART SECOND.

OF THE ADIPOSE TISSUE.

The adipose tissue ought to be regarded as a distinct modification of the cellular membrane, because the cells in which the fat is lodged, do not communicate with those which contain the lymph or serosity. This distinction between the two tissues was first observed by Dr. W. Hunter, who thought that there was a particular organization or glandular apparatus superadded to the reticular membrane, consisting of vesicles for lodging the animal oil, and of vessels fitted for its secretion.* These bags, which are distinct from those containing the air in emphysema, or the water in anasarca, he calls adipose cells, in opposition to the general ones, which he calls reticulated. This opinion, which has been adopted by Prochaska, Mascagni, Chaussier, and Gordon, has been supported, with great ability, by Beclard. The distinct existence of the adipose tissue was denied by Haller, and afterwards by Bichat and Meckel. In investigating the nature of the adipose cells, I shall endeavour to shew that the opinion of Haller is not correct; for although these vesicles are seldom, if ever, met with, unaccompanied by cellular substance, yet that circumstance does not establish their identity.

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* Med. Obs. and Inquir. vol. ii. p. 33.

SECTION I.

PROPERTIES OF THE ADIPOSE TISSUE.

THE adipose tissue admits of a division into two parts, according as it is met with generally in the body, or as it is confined in the interior of the bones. The first portion is that which we have now to consider; the second is connected with the medullary membrane, and will be described with the osseous structure.

There are two forms under which fat is seen: the free state, when it is evident to the naked eye; and the state of combination, in which condition chemical agents are required, in order to detect its existence.

There are but few parts of the body, in which fat is not found at some time or other in its free state. In the early periods of life, it is accumulated in large quantities on the surface of the body, immediately under the skin; and it is to this circumstance, that the fulness and plumpness of infants are owing. In old persons, on the contrary, this substance is met with in the cavities of the body, as around the heart, the stomach, intestines, &c.

The adipose matter is very abundant on the face, especially on the cheeks and in the orbits. It is in larger quantity on the anterior than on the posterior part of the neck. In the thorax, the fatty tissue is met with in the anterior and posterior mediastina; around the heart, especially in age, and in the intercostal spaces; on the exterior of the chest, it is principally found about the mammæ, where, in the female, it often accumulates in large masses; also between and around the pectoral muscles. There is no part of the body which contains so much of this structure as the abdomen, both without and within. In the interior of this cavity, it is placed between the folds of the peritoneum, as in the mesentery, mesocolon, and omenta; also around the kidneys, and in the pelvis. On the exterior, the fat is lodged between the skin and abdominal muscles, where, in cases of obesity, it is occasionally collected in an enormous quantity. In the limbs, the adipose tissue is found in the palm of the hand, in the axilla, in the sole of the foot, in the ham, and in the groin. The nates are formed, in a great measure, of adeps, which in this place constitutes a couch for resting on in the sitting posture.

Fat is found between the fasciculi and fibres of the muscles which are submitted to the influence of the will; it is distinguished between the lobes of the lobulated glands; the sheaths of the vessels enclose a very little; the nervous cords possess small masses of it between their fibres; and the coarse fasciculi of the ligaments are, in part, separated by the adipose tissue.

There are certain parts of the body which contain no fat in its free state; viz. the interior of the cranium, of the brain, the eye, the ear, and the nose; also the substance of the lungs, of the intestines, and of many glands, particularly the lymphatic. This substance is also wanting in the eyelids, in the penis, the scrotum, and the nymphæ. It is also deficient around the long and slender tendons, and in the intervals between many of the muscles which execute great movements. Lastly, it may be stated, that there are organs in which adeps never is deposited, notwithstanding there is great obesity; and, on the contrary, that there are parts in which it never entirely disappears, although in other respects there may be complete marasmus.

As the quantity of the fat in its free state is liable to such great variation, no very accurate estimate can be made of its proportion to the whole of the body; but it is said that, in an adult of ordinary stoutness, the fat forms about the twentieth part of the body. In cases of obesity it forms from a half to four-fifths of the total weight of the body; on the contrary, in great emaciation, the fat exists only in a few places, and in diminished quantity. The female body in general possesses more of this substance than that of the male. The proportion varies according to age, and other circumstances. During the first half of the fœtal existence, the fat is entirely deficient. It begins to appear at about the fifth month, in isolated grains, under the skin; at the period of birth this is the only region where it is accumulated into a mass, as the adeps in the internal organs is either altogether wanting, or found in small and distinct grains. In advanced age, the body becomes very thin, in consequence of the diminution of the quantity of fat. Thus the two extremes of existence resemble each other in this respect; but the body of the old person differs from that of the infant in the situation of the fat which it contains: in the former, there is very little on the external surface, but a considerable quantity in the very substance of the organs; in the latter, on the contrary, there is comparatively a large proportion under the skin, and little or none in the interior of the body.

Many circumstances tend to increase the quantity of fat, especially rest and nutritious diet; and in the human species, the absence of all anxiety and of intellectual exertion. The loss of the venereal appetite, caused by the removal of the testicles in the male, and of the ovaries in the female, tends greatly to produce obesity. The opposite conditions diminish the volume of the adipose structure; such is the effect of great mental or corporeal exertion, excess in venery, or insufficient and bad food.

The density of the adipose tissue is not the same in all parts of its extent. The degree of firmness depends on that of the cellular texture, by which the vesicles and masses are surrounded. The small grains of fat are plunged in a very delicate cellular substance, which it is difficult to observe; but between the larger masses the connecting medium is more evident, and at length becomes very apparent. In some places, as in the orbit, face, and axilla, the cellular tissue is soft and lax; on the cranium and back, firm cellular layers support and unite the adipose masses; while in the sole of the foot and palm of the hand, but especially in the former, there are very dense and resisting fibrous layers, which greatly increase the firmness of the fatty tissue.

SECTION II.

COMPOSITION AND ORGANIZATION OF THE ADIPOSE TISSUE.

THIS tissue consists of masses which vary in their magnitude and shape; in some places they are as large as peas, and even as hazel-nuts. Each of these bodies is composed of grains, and these, when viewed with the microscope, appear to be formed of vesicles, the diameter of which varies from the eight hundredth to the six hundredth part of an inch. The size, which is not the same in all animals, successively increases, according to Wolff, in the hen, in the goose, in man, in the ox, and in the pig. In the different parts of the human body, the size of the vesicles is the same, although that of the masses infinitely varies.

They are generally obround in form; but in the orbits, in the thickness of the cheeks, in the interior of the pelvis, before the pubes, in the neighbourhood of the kidneys, &c. they are round. In the omentum and appendices epiploicæ, the masses are pyriform or pediculated. Those which are met with in the median line of the abdomen, are ovoid, having one end placed in the skin, and the other in the aponeurosis. The fat under the linea alba sometimes projects through it, and becoming hardened, resembles, in some respects, an omental and ventral hernia. Scarpa states, that he once committed the error of operating on a fatty tumour which he thought was a hernia.

The fatty tissue may then be regarded as composed of conglomerated vesicles, which are united into grains, and these in their turn, are collected together to form masses. It is true the parietes of the vesicles are so delicate, that they cannot be anatomically demonstrated; but there are proofs to shew, that they actually exist. It would be difficult otherwise to account for the constant and regular forms, which the adipose masses and their component parts present. Haller, and since him Meckel, have said that this form is inherent to fat, and independent of its situation in the cellular tissue. But this is incorrect; for when fat is removed from its containing structure, it possesses no globules with the determined form assigned to them by Haller. If some of these vesicles are placed in tepid water, no oil can be perceived by the microscope on the surface; but when they are cut, some drops immediately escape, which float on the liquid.* If the fat were contained in the same cells as the serosity, being fluid during life, it ought to obey the laws of gravity. But this does not take place, for the fat never accumulates in the scrotum or penis, in the most extreme cases of obesity, although in anasarcous cases those parts are much distended. Again, the water in dropsy, the air in emphysema, and the blood in extravasation of that fluid, recede upon pressure, which produces what is technically called *pitting;* and the same thing happens in the dead body when oil is thrown into the reticular or cellular membrane; the fluid produces an œdematous feel, and it can be pressed from one part to another, as if it were water. But the natural oil of the adipose membrane, although it may exist in a large quantity, cannot be pressed from one part to another.† The preceding circumstances render it most probable that the vesicles do not communicate. Some naturalists have absurdly attributed the formation of the pendulous breasts of some women, and the enlarged nates of others, to the gravitation of the fat.

The observations that were made concerning the vessels of the cellular tissue, may be generally applied to those of the adipose substance. The arteries can be readily injected, especially in young subjects—they ramify in the intervening cellular tissue, and end at the microscopic vesicles, where they secrete the fat which the latter contain. The absorbents are less distinct, and their existence is rather admitted from the functions of the tissue than from any anatomical demonstration of them. Mascagni speaks of an external and internal layer of lymphatic vessels, as forming the vesicles; but he relates no fact in support of this opinion. No nerves have been traced in the vesicles, although filaments may be followed in the general cellular substance to a considerable degree of minuteness.*

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* Beclard, Anat. Gen. p. 161.

† Dr. Hunter, l. c. pp. 35, 36.

SECTION III.

OF THE PROPERTIES OF FAT.

THE colour of fat, which is a yellowish white, varies in the different epochs of life, being whiter and more transparent in proportion to the youth of the animal. The yellow colour is owing to a peculiar colouring principle, which being soluble in water, is lost by washing the fat. The human fat, when it is removed from its vesicles, has all the characters of fixed oils. After it has been purified, it is inodorous, and of a mild and insipid taste; it is lighter than water, and is fluid at the temperature of the body. It burns with rapidity; and by exposure to air and light, it becomes rancid, and gives off a volatile acid, which has a strong odour. By the action of alkaline substances, animal fat yields margaric and oleic acids, and the mild principle called glycerine.† Fat is one of the few animal substances which do not contain azote; it is composed of carbon, hydrogen, and oxygen.

Fat was considered as one of the immediate principles of organization, till M. Chevreul proved that it was formed of two substances: one fluid, called elaïne; the other solid, called stearine. The former substance continues fluid at zero, and does not take a solid form till some degrees below it. It is colourless, and has the appearance of oil; it is almost inodorous, and has a mild taste. The stearine is white, and rather shining; and it is readily fused when heated. The degree of the combustibility of fat depends on the proportion of these two substances. They can be separated by treating fat in boiling alcohol; in cooling, the greatest part of the stearine is precipitated in the form of very small white crystalline needles. The elaïne remains in solution with the alcohol, and may be obtained by evaporation.

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* Gordon, Sys. of Anat. p. 224.

† Turner's Elements of Chem. p. 736.

SECTION IV.

FUNCTIONS OF THE ADIPOSE TISSUE.

THE functions of the adipose tissue are not well understood, although there has been much discussion on this subject. Regarding this tissue by itself, its most evident office is to secrete the fat which it contains. Many anatomists have erroneously supposed, that there is a glandular apparatus for the secretion of the adeps; but this secretion is neither effected by means of glands nor of follicles; it is merely the result of the perspiratory action of the arteries which supply the vesicles of the adipose tissue. As I have already shewn how totally unacquainted we are with the process of secretion, it is needless to inquire, in this place, by what means the separation of the fat from the blood is accomplished. It has been asked, in what part is the fat formed? Is it formed in the vessels of the adipose vesicles, in the blood, or, as Sir E. Home has supposed, in the chyle? The observations of Chevreul, Thackrah, and Traill, prove that the blood contains fat, which is most probably derived from the chyle. It appears that the materials of fat, like those of all other secretions, exist in the blood; and that by some peculiar process, it is separated by the vessels of the adipose tissue.

The adipose tissue, regarded as an entire organ, has other offices in the economy. Some of these are simply mechanical; thus by its position, it moderates the effects of pressure, as in the sole of the foot and on the nates; in some places it supports and thus defends certain organs; for instance, in the orbit it constitutes a soft couch for the reception of the globe of the eye. Conjointly with the cellular tissue, it assists in filling up the voids which would otherwise exist, and in this manner it assists in producing and preserving the rounded form proper to animals. As fat is a bad conductor of caloric, it has been supposed that it assists in preserving the temperature of the internal parts of the body. Some physiologists have thought that the fat renders the surrounding parts supple, and others have even imagined that it might defend and oil the skin by a kind of transudation. There is no proof to substantiate the first of these opinions, and the second is undoubtedly erroneous, for there is a special apparatus provided in the sebaceous follicles, for the secretion and defence of the skin.

The most general use of the adipose tissue, is to serve as a reservoir of nourishment, the fat which is contained in its cells frequently undergoing absorption, when nutrition, by means of digestion, is for a time suspended. This is strikingly illustrated in hibernating animals, which are very fat when they fall into the torpid state, but at the return of spring, they are much reduced in bulk. A very curious instance of life being supported by the absorption of the fluids of the body, occurred some years since at Dover. A hog weighing one hundred and sixty pounds, was buried under a portion of the cliff, which fell on its stye, for the long space of one hundred and sixty days. At the end of this time, being dug out, it weighed only forty pounds, and was extremely emaciated, clean, and white. As there was neither food nor water in the stye when the cliff fell, this hog must have existed during the time mentioned, by the removal of the adipose and other fluids from their containing structures, into the circulating system.

It has been said by Beclard, that the nutritious matter passes through many states before it is assimilated with the body, and he thinks that the fat is one of these conditions. I believe that this is not correct, because the nutrition of the body is very often carried on in a perfect manner when there is no fat, as in the fœtus, or when it exists in a small quantity, as in persons who take great exercise, such as boxers and jockeys. There can be no doubt that the assimilation of the nutritive matter is accomplished, when the chyle, having undergone the pulmonary circulation, is converted into arterial blood.

CHAPTER SECOND.

OF THE SEROUS MEMBRANES.

In the elaborate work of Bichat, the nervous and the vascular systems are described immediately after the cellular tissue. But it appears preferable to consider in a successive order, according to their degrees of complication, the various modifications of the cellular substance, before proceeding to the nervous system, which is composed of a totally distinct structure.

The term of *serous membrane*, as it is usually employed, applies only to the membranes of this class, which are placed in the great cavities of the body. But the best anatomists of the continent include, under the general denomination of serous system, not only the membranes of the head, chest, and abdomen, but also the synovial membranes of the joints and tendons. Although there are so many points of resemblance between the two kinds of membranes, that this classification appears to be well founded, yet it must be borne in mind, that they exhibit several differences in their mode of connexion, and particularly in the nature of the fluid which they exhale.

The numerous organs, which according to this view of the subject, are included in this system, require to be divided into two great classes :—1. The serous membranes, properly so called, comprehending those of the great cavities, viz. the tunica arachnoides, contained in the head and spinal column; the pericardium and the pleura, placed in the chest; the peritoneum lodged in the abdomen; and its processes, the tunicæ vaginales, in the scrotum. 2. The synovial membranes, which consist of those of the articulations, of the tendons, and of those which are subcutaneous; the membranes of the two last species are distinguished by the name of *bursæ mucosæ*.

It is doubtful if the delicate production that lines the chambers of the eye, the *membrana humoris aquei*, ought not to be included in this system. The lining membrane of the blood-vessels also bears a striking resemblance to the serous membranes, and probably consists essentially of the same structure.

I shall divide the present chapter into three parts: in the first part the properties which are possessed in common by all parts of the serous system, will be considered; in the second part, the characters of the synovial membranes, and in the third, those of the splanchnic serous membranes will be separately investigated.

sition can be readily understood in many parts, as in the urinary bladder, in the cœcum, the ascending and descending portions of the colon, &c.; but it is more difficult to comprehend it in other parts; thus the convolutions of the small intestines appear to be within the peritoneum, the heart within the pericardium, &c. It is also necessary to state, that in consequence of this sack-like form, the viscera, and other bodies that are connected with the reflected serous membranes, are only partially cloathed by them; there is no exception to this rule, so that however much any organ may be surrounded by a serous tunic, there is always one point, at least, at which the membrane is deficient, viz. where the vessels and nerves enter. The only difference between the viscera in this respect is, that some are more covered than others; thus the small intestines are devoid of the peritoneum only on one point, while the stomach and the colon are uncovered in two places.

The reflexion of these membranes produces in many parts, folds or duplicatures, which contain vessels and nerves, or fat and cellular tissue, or, as often happens, all these together. They are distinct in the peritoneum, where, forming a species of ligament, they sustain many of the viscera; in the pleura there is also a fold for conveying the vessels and other parts belonging to the organization of the lungs. There are likewise duplicatures of another kind, which are loose and floating in the serous membranes; such are the omentum and the appendices epiploicæ, in the abdomen; the fatty folds of the pleura, on the sides of the mediastinum; and, lastly, the fringes of the synovial membranes, in some of the articulations.

Every serous membrane possesses two surfaces, one of which, the external, is generally adherent, while the other or internal, is free and unattached.

The external surface, with the exception of the tunica arachnoides, which in some places is free on both sides, is connected to the neighbouring organs by means of cellular substance, which is distinguished from its situation, by the name of the subserous cellular tissue.* The firmness of this connexion is liable to great variation; for example, the peritoneum adheres so weakly to the urinary bladder, to the duodenum, and to the pancreas, that it may be stripped off those viscera: it is on the contrary closely connected to the other parts of the digestive apparatus. Again, the tunica arachnoides is so loosely attached to the pia mater, that it is readily separated by inflation with the blow-pipe, whilst it adheres so firmly to the dura mater, that a careful dissection is required to shew the distinctness of the two membranes. There is not, however, in any part so strict a union, as that which is formed between the synovial membrane and the articular cartilages. This connexion is indeed so intimate, that the extension of the synovial membrane over the cartilages, was denied by the late Dr. Gordon, and more recently, by M. Magendie. The former in speaking of this subject, says, "the continuation of the synovial membrane over the surface of articular cartilages, (a distribution more than hinted at by Dr. Nesbitt and Dr. Hunter, and confidently maintained by Bichat,) is, I am convinced from a number of experiments, altogether an anatomical *refinement*." It must, however, be recollected, that Dr. Gordon had similar doubts concerning the continuity of the tunica conjunctiva over the cornea, a continuation which is now admitted by the best anatomists and pathologists. I have a preparation which shews a portion of the synovial membrane with its vessels, beautifully distinct, extending over the articular cartilage of a fœtal calf.

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* See p. 114.

The internal or *free surface* of the serous membranes, is distinguished from all other structures, by its smooth and polished appearance. This polish, which is so strongly characteristic of the tissue we are considering, facilitates in a striking manner, the movements of the internal organs, and of the numerous joints. It has been well observed by Bichat, that nature has provided two essential means for the defence of the body, in the constant and varied motions which are required in the operations of the economy, viz. the cellular tissue and the serous membranes; wherever there is motion, one or both of these textures are observed.

Although the internal surface appears to the naked eye to be perfectly smooth, yet when it is examined with the aid of the microscope, it presents innumerable, but evident villosities or small projecting bodies. These minute eminences are frequently rendered visible to the naked eye, after inflammation of the serous membranes. If the finger be passed over a part which is thus altered, as the peritoneum or pericardium, it feels gritty, and as if it were covered with sand.

The free surface of these membranes is every where contiguous to itself; but although it is in perfect apposition, there does not exist, in the natural condition, any connexion or adhesion. Nothing, however, is more common than to find adhesions of this side of the serous membranes; in fact, the body of an adult is seldom opened, without some of these morbid changes being found in one or other of the great cavities. They are principally confined to the serous membranes, properly so called, although they occasionally exist in the synovial system.

The different organs that are provided with serous envelopes, are, in a certain degree, insulated, by their free surface from the surrounding structures. Bichat instances, as a proof of this disposition, the relations of the principal viscera, as the heart, the brain, the abdominal viscera, the testes, &c., which, being suspended in their proper sacks, only communicate with the adjacent organs at the place where their vessels enter. This statement is perfectly correct in an anatomical point of view, but Bichat has gone farther, and wishes to prove that the serous membranes serve as limits to the extension of diseased action. The opinion of this ingenious physiologist is, however, but ill-supported by facts, for observation too frequently shews that disease invades these imaginary barriers of the serous membranes, and extends its ravages from organ to organ.

SECTION II.

ORGANIZATION OF THE SEROUS MEMBRANES.

THE serous tissue ought to be regarded as a simple modification of the cellular substance, since it may be reduced by maceration into a similar texture. It seems to be almost homogeneous, but on close inspection a fibrous appearance may be detected in many parts of its extent. The colour of these membranes cannot be perceived in many parts on account of their perfect transparency; when they are sufficiently opake to reflect the light from their surface, it is seen that they are greyish white. They are, in general, very thin; so that it is only with great difficulty that they can be separated from the adjacent parts; in fact, in some places, this cannot be accomplished. The degree of tenuity is, however, subject to variation, as may be readily observed on comparing the pleura costalis, or the parietal portion of the peritoneum with the delicate arachnoid tunic.

The serous membranes, in a state of health, receive no vessels which admit the colouring part of the blood; although numerous arteries and veins filled with a red fluid may be detected in the subserous cellular structure. It is generally supposed, that they are provided with a great number of colourless vessels which are distinguished by the name of exhalants; these are so minute, that they escape the observation of the eye, except inflammation be present, when in consequence of the red blood being forced into them, they are rendered apparent. The term of *exhalants* has been lately objected to, because there is great cause to doubt if the secretion of the serous membranes is accomplished by means of such tubes as were described by Bichat.

The lymphatics appear to be numerous, but Mascagni has committed a serious error in supposing that the serous tissue is entirely composed of these vessels. The nerves of this system have never been traced, although they may be seen ramifying on the parts with which its external surface is connected.

SECTION III.

PROPERTIES AND FUNCTIONS.

THE serous membranes, in proportion to their thickness, are very firm and resisting. This property is illustrated by the following experiment, which was performed by Scarpa: a portion of the peritoneum was stretched over a hoop, and he found that it did not give way till a weight of 15 lbs. had been placed on its surface.

The resistance to rupture does not, however, altogether depend upon the firmness of these membranes; but in part on the great power of extensibility by which they are characterised, and in virtue of which they are enabled to adapt themselves to those changes of position that are so often rendered necessary in the operations of the economy. Closely allied with the exercise of this property, there is another apparently depending merely on elasticity, which is called the contractility or tonicity of the serous tissue. These two properties are principally displayed by the membranes of the great cavities of the body; thus in the varied movements of the vertebral column, the spinal portion of the arachnoid yields and recovers itself with great facility; again, the pleura being alternately extended and contracted, follows incessantly the motions of the ribs, and the pericardium is as constantly influenced by the diastole and systole of the heart. It is, however, in the peritoneum that extensibility and elasticity are most strikingly exhibited; equally affected with the pleura by the movements of respiration, this membrane is also influenced by all those changes which occur in the size of the viscera during the process of digestion; there is an instance of this in the sudden distension of the serous coat of the stomach after a hearty meal, and in its more gradual contraction as that organ becomes emptied of its contents. Pregnancy, dropsy, and hernia, also demonstrate to what a degree the peritoneum may be extended without tearing, and how readily and completely it returns to its former condition when the distension ceases. The enlargement in these remarkable cases does not entirely result from the extensibility of this membrane; it depends in part on the disappearance of those folds, which are provided by nature to guard against laceration when the size of the viscera is so amazingly increased; it is in this manner that the stomach, when greatly distended, glides between the layers of the omentum, and the uterus between the laminæ of its broad ligaments. It also appears, that in some instances there is an actual growth of the serous membrane, as in pregnancy and in large hernia. The synovial membranes, protected by their disposition from any great distension, possess the above properties in a less degree than the other parts of this system.

The serous membranes present no marks of contractility on being irritated in a living animal; they are also insensible in their healthy state, although they become painful in inflammation.

The internal surface of the serous system is constantly bedewed with a fluid which is derived from the minute arteries, but by what mechanism it is difficult to determine. In the chapters on the cellular and vascular systems, I have alluded to the theories which have been brought forward to explain the phenomena of exhalation and absorption; and to those observations I refer the reader for farther information on this interesting subject. The fluid that is separated from the arteries is immediately absorbed, and again carried into the circulation; but if any cause disturbs this balance of secretion and absorption, an accumulation occurs which constitutes dropsy. During life these fluids, with the exception of the synovia, appear to be secreted in the form of vapour, although after death, in consequence of the loss of caloric, they are converted into a liquid, which has a great resemblance to the serum of the blood. The secretions of the different serous membranes present some variations in their chemical composition, which principally concern the quantity of albumen they contain.

The specific and essential uses of the serous membranes, in whatever part of the body they may be placed, is the same; they facilitate in a remarkable manner the movements of the organs which they cover; and being lubricated by an albuminous fluid, they also insulate these organs, however contiguous they may be, and thus prevent them adhering together. It has been stated, but with little appearance of probability, that the portion of the blood which is alternately deposited and absorbed by the serous membranes, thereby undergoes such changes that it is more completely assimilated and better adapted for the nourishment of the body.*

SECTION IV.

DEVELOPMENT OF THE SEROUS SYSTEM.

THESE membranes present variations in their characters in the different periods of existence, but they are few in number and comparatively unimportant. This system, like all others, is very soft in its origin, so that the abdominal viscera appear at first to be covered merely by a viscid fluid, which gradually acquires consistency. In consequence of this softness, the membranes can be more easily separated from the organs they are connected with than later in life; their reflected layer, however, adheres so intimately in many places, that it is difficult, even in this early period, to accomplish its separation. The form and disposition of these membranes in the beginning, are very imperfectly known. Meckel thinks it is probable that several among them, as the pericardium and the peritoneum, are open in the principle and obtain the sac-like figure at a more advanced period. The peritoneum has certain peculiarities in the neighbourhood of the umbilical opening, and also of the inguinal canal in the male fœtus, which subsequently disappear. The serous membranes undergo certain changes in old age, which principally relate to their density and to the number of their vessels.

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* Beclard, Anat. Gen. p. 191.

PART SECOND.

OF THE SYNOVIAL MEMBRANES.

THESE membranes may be divided in three classes. 1. The subcutaneous bursæ mucosæ. 2. The bursæ mucosæ of the tendons. 3. The synovial capsules of the articulations.

SECTION I.

OF THE SUBCUTANEOUS BURSÆ MUCOSÆ.

THESE organs, *bursæ mucosæ subcutaneæ*, are composed of simple sacks of the synovial membrane, and have, like all other parts of the system, an external surface attached to the surrounding cellular tissue, and an internal surface which secretes an oily fluid, and is every where continuous with itself. They are placed on those parts of the exterior of the body which are subject to pressure and to frequent movements; the largest are situated between the patella and the skin, on the trochanter major, the olecranon, and the acromion; also on the dorsal sides of the joints between the fingers and metacarpus, and on the joints between the first and second phalanges; the same structures are likewise placed on the corresponding articulations of the toes. The subcutaneous bursæ of the fingers and toes are usually confounded with those of the neighbouring tendons; they are best exposed by making an opening and inflating them; a little care is necessary in doing this, or they will not be distinguished from the cellular texture. The bag of which the bursa is composed, is of an oval shape, and it appears, when inflated, somewhat sacculated, on account of there being within it some imperfect partitions; the parietes are very thin, and only slightly resistant. These bursæ, which appear to be a very slight modification of the cellular tissue, facilitate the movements of the limbs and other parts on which they are placed. They sometimes become very apparent in consequence of enlargement; the one which is between the patella and the integument, is particularly liable to be thickened and enlarged in persons who are much in the habit of resting on the knee, as carpenters and housemaids; and even, according to some continental writers, priests have suffered in the same part from frequent kneeling.

SECTION II.

OF THE BURSÆ MUCOSÆ OF THE TENDONS.

THE bursæ of the tendons, *bursæ mucosæ tendinum*, are rather more complicated than those of the preceding class; they are placed in all parts of the body where tendons are liable to friction; and, according to their disposition, they are divided into two sets. The first species, called, on account of their figure, *bursæ mucosæ vesiculares*, consist of rounded bags, which are attached on the one side to the tendon and on the other to the part, whatever it may be, on which the tendon glides;

there are examples of these structures, where the obturator internus lies between the gemini, in the place where the tendon of the extensor carpi ulnaris lies against the lower extremity of the ulna, &c. Those of the second species are more complicated; they are called synovial sheaths, or vaginiform processes, *bursæ mucosæ vaginales*. These structures resemble some of the more simple of the reflected serous membranes, such as the pericardium; one part of the sheath surrounds the tendon, and is closely adherent to it; the second, or reflected part, lines the canal which lodges the tendon; these two portions of the membrane are continuous with each other at their extremities; that is, where the loose portion is reflected. The vaginiform bursæ are met with around many of the tendons belonging to the long muscles of the limbs; as on the flexors of the fingers, of the toes, &c. It often happens, especially in the articulations of the hand and foot, that the tendons of several muscles are contained in a common sheath; frequently, however, the sheath presents as many duplicatures and partitions as there are tendons, so that each of the latter receives a proper and distinct process. In some places, as on the palmar surface of the phalanges, the arrangement of these sheaths is rendered still more complex from the circumstance of there being several little cords or threads within them, called ligamenta accessoria, each of which is provided with its delicate covering of the synovial membrane.

The tendinous bursæ constitute closed sacks, and consequently each of them possesses a free and an adherent surface; the former is smooth and lubricated by the peculiar oily fluid which is secreted in the synovial system;

the latter is closely attached to the tendon and to the surrounding parts.

These sheaths are provided in the situations where tendons are exposed to friction ; as, for example, where tendons cross over bones, and especially in those places at which their course is altered by passing behind processes, over pulleys, through grooves, &c. ; it is evident from this statement, that the greater number of the tendinous bursæ must be disposed near the articulations of the limbs ; as in the neighbourhood of the shoulder, elbow, and wrist ; and of the hip, knee, and ankle.

In some of these bursæ there are fringes, which consist of folds of the membrane ; they may be seen in several of the sheaths behind the inner malleolus ; fatty processes which have been incorrectly compared to excretory ducts, may also be observed in some of the vesiculated bursæ. The synovial membranes of the tendons are of a whitish colour, and semi-transparent ; they are thin, but firm in texture ; the vesiculated bursæ are thicker than the vaginiform ; both appear to be modifications of the common cellular tissue. They possess numerous small arteries, and some which also admit the coloured blood. No lymphatic vessels have as yet been satisfactorily demonstrated, but it may be presumed that they exist. No nerves have been traced in these structures.

The use of the bursæ is to facilitate the movements of the tendons, by allowing them freely to play against the parts with which they are in contact ; this is readily effected by means of the oily fluid which is secreted by the free surface.

SECTION III.

OF THE SYNOVIAL ARTICULAR CAPSULES.

THE membranes distinguished by this term, *capsulæ synoviales*, are the most important, and at the same time the most complicated of the synovial system. They belong principally to the moveable articulations of the bones, although a few of them are connected with the cartilages of the larynx and ribs. They were for a long time confounded with the ligaments; but they have been distinguished from those organs, and also from the cartilages, by Nesbitt, Dr. Hunter, and other writers. Dr. Monro in his excellent work on the bursæ mucosæ, speaks of the similarity of these and the other synovial membranes, with the serous membranes; this resemblance has been noticed by many later anatomists, as Meckel, Gordon, and Cloquet. We are indebted to Bichat for the most correct information respecting the character and arrangement of the synovial capsules; but he appears to have committed an error in separating them from the general serous system; for although differences certainly exist between the two kinds of organs, yet they are not sufficiently important to justify an anatomical distinction.

The number of the articular synovial membranes is nearly the same as that of the moveable joints within which they are placed. Each of these membranes, as was most satisfactorily shewn by Bichat* forms a sack, which is reflected on the articular cartilages, on the internal surface of the capsular and lateral ligaments, and, when they exist, on all the interarticular ligaments. The smooth and polished surface which these parts possess, is owing to their synovial covering. There is the same relation between the cartilages, ligaments, &c., and the articular synovial membrane, as there is in the other parts of the serous system; that is to say, they are all placed without the lining membrane, although they appear to project into its cavity.

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* Anat. Gen. t. ii. p. 582.

In many of the articulations, the fibrous capsule is deficient, and there is little else but synovial membrane; this is the case in the knee, and in the ankle; also on the back part of the elbow, on the dorsal sides of the joints of the fingers and toes; the thin capsule is, however, strengthened by some condensed cellular membrane, and in some of these joints, by the addition of fascia or tendons.

The disposition of these membranes offers many varieties, some of them form simple sacks, as those of the phalanges, carpus, wrist, &c.; others are less simple, as in addition to forming a bag which covers the cartilages and ligaments of the joint, they furnish sheaths to the ligaments or tendons which may be within the articulation; thus in the hip, the synovial membrane is reflected over the ligamentum teres, and in the shoulder, around the long head of the biceps. The most complicated of these membranes is that of the knee, which covers the ends of the bones, and also lines the crucial ligaments and the semi-lunar cartilages.

The external surface of the synovial capsule adheres with various degrees of firmness to the articular cartilages, and to the different ligaments; the connexion between the membrane and the ligaments is of such a nature, that, by careful dissection, a separation may be effected; but this observation cannot be applied to the portion which covers the cartilage. It has already been stated, that Dr. Gordon, in opposition to Nesbitt, W. Hunter, Bichat, &c., denied the continuity of this membrane over the articular cartilage, and a similar opinion is supported by M. Magendie. I have myself no doubt of the correctness of Bichat's statement, because the vessels of the membrane may be traced in inflammation over the circumference of the cartilage, and in a very successful injection, they may be filled with size and vermilion.

The internal or free surface, which is every where contiguous to itself, is polished and lubricated by the synovial fluid. It often presents folds, which contain fat, and project into the joints; they are vascular, and from this circumstance they have a reddish colour. These duplicatures have been called the glands of Havers, because that anatomist, who first spoke of them in a definite manner, considered them as glandular. He supposed that the synovia was secreted by these bodies, and was conveyed into the joints by proper ducts. The fatty masses which Havers mistook for glands, are very evident in the hip joint, and in the knee. This opinion prevailed to the time of Monro, who gave us more accurate ideas of the synovial membranes. He denied the existence of any glandular body within the above masses of fat; but he committed a serious error by supposing that the synovia was secreted by follicles, which he compared to those of the urethra. In the present day, it is known that the secretion of the joints is performed neither by glands nor follicles, but like that of the serous membranes in general, by exhalation.

The synovial capsules are thin and firm, in order to prevent the escape of the contained fluid; they are also semi-transparent, and of a whitish colour. They are capable of a certain degree of extension, as is manifested in accumulation within the joints. They are likewise retractile or elastic, but not to the extent of the splanchnic serous membranes. The degree of elasticity which these membranes possess, cannot be accurately estimated, because they are so closely attached to the inner surface of the ligaments, which are nearly inelastic, that they cannot contract when the distending force is removed. The only office which the synovial articular capsules fulfil in the economy, is that of facilitating the motions of the body by lubricating the cartilaginous extremities of the bones.

SECTION IV.

OF THE SYNOVIA.

I HAVE deferred speaking of the secretion of the bursæ mucosæ, until the articular membranes were described, because the nature of the fluids is the same in both structures.

The secretion of the synovial system consists of an oily and albuminous fluid, which is called, from its resemblance to the white of an egg, *synovia*. It is very viscid, and at the same time remarkably soft, smooth, and slippery; it has a saltish taste and a slight odour. Its specific gravity exceeds that of water, in the proportion of one hundred and five to one hundred. The synovia of the human subject consists of a yellowish fat, albumen, an uncoagulable animal matter, soda, and chlorate of potassium and sodium, which substances are held in solution by a large quantity of water. It has been lately shewn by Orfila, that fibrin is one of the constituent principles of this fluid; a trace of the phosphate of lime has also been detected, together with gelatine, mucus, and an animal matter, which is said to be uric acid. The albumen is concreted by the action of heat, alcohol, and the mineral acids.

The use of the synovial fluid is to diminish the effects of friction, and to aid in a powerful manner the motions of the various parts of the body.

PART THIRD.

OF THE SPLANCHNIC SEROUS MEMBRANES.

UNDER this denomination are comprehended the membranes which line the great cavities of the body, and also furnish a more or less perfect envelope to the contained viscera. The resemblance which exists between them and the synovial membranes, was pointed out by Dr. Monro;* but Bichat appears to be the first anatomist who has given an exact and complete description of the organs belonging to the serous system.

The proper serous membranes consist of—1. The peritoneum, lining the parietes and viscera of the abdomen. 2. The pleura, connected in a similar manner with the chest and lungs. 3. The pericardium, surrounding the heart. 4. The tunica arachnoides, covering the brain, the spinal cord, and the dura mater. 5. The tunica vaginalis or perididymis, investing the testicle, and derived from the peritoneum. The membrane which encloses the fœtus, called the amnios, has a considerable resemblance to the serous tissue, and ought perhaps to be classed with the above structures.

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* Descript. of the Bursæ Mucosæ, p. 37.

SECTION I.

FORM AND DISPOSITION.

WE perceive from the preceding enumeration, that the serous membranes surround the organs which are the most essential to the support of life; and it is remarkable, that these organs are generally lined on the opposite side by the mucous membranes; there are, however, exceptions to this arrangement, for in some places, as around the brain, the heart, and the testes, the serous membrane is met with separately, while other parts, as the nostrils, the mouth, and the œsophagus, are only provided with a mucous lining. Bichat, regarding the serous membranes collectively, concludes that they are more extensive than the membranes belonging to the mucous system, but the correctness of this opinion may be questioned, especially when the ramified disposition of the latter structure in the interior of the lungs, of the liver, of the kidneys, &c., is compared with the simple covering which is furnished on the exterior of these organs by the serous tissue.

In the general description of the serous system, the principal facts connected with the membranes under consideration have been mentioned. Each of them forms a closed sack, which is in some instances rendered very complicated by the reflexions it undergoes; one portion of the membrane gives a covering to the walls of the cavity in which it is placed, and another portion affords an envelope to the contained viscera, so that every serous bag possesses a *parietal* and a *visceral* layer, which are continuous with each other at the point of reflexion. The pleuræ, the pericardium, and the tunica vaginalis are simple in their arrangement, and are consequently readily comprehended, but the connexions of the tunica arachnoides, and especially of the peritoneum, are more intricate, and require a very careful examination before they can be understood. In proceeding with such an investigation, the principal characters of the serous membranes must be borne in mind: viz. that they are closed sacks, that they are reflected, and that the viscera are placed on their external surface.

The tunica arachnoides covers the surface of the brain, and, passing into the aperture discovered by Bichat, it lines the ventricles; it is also reflected on the inner part of the dura mater. At the base of the encephalon it furnishes a sheath to each of the nerves, which extends as far as the point where the nerve quits the cranium, at which place it is reflected to the dura mater. The arachnoid also covers the spinal cord, and sends off processes, which invest the nerves, till they quit the theca vertebralis, when the membrane passes on to the spinal portion of the dura mater which it lines throughout its whole extent.

The connexion which exists between the peritoneum and the viscera of the abdomen, is liable to considerable variation, but it may be stated, that in general those organs which are placed near the parietes have a very imperfect covering, and are fixed in their situation; whilst those which are farther removed from the walls, possess a more perfect peritoneal tunic, and also enjoy a greater extent of motion. The peritoneum is united in such a manner with the viscera, that it allows of those changes in the size of the organs, which so frequently occur; for example, the two layers of membrane that form the mesentery, the great omentum, and the broad ligament of the uterus, are so loosely joined to each other by the cellular texture, that they readily separate when the organ connected with them is enlarged or distended beyond a certain degree. Thus, if the stomach be much increased in size, it glides between the layers of the omentum, and a similar change is exhibited, but in a more striking degree, during pregnancy, in which state the enlarged uterus gradually separates the folds of the broad ligaments, till eventually they become obliterated.

The splanchnic serous membranes have an adherent and a free surface. The external or attached surface is connected either to the parietes of the cavities, or to the exterior of the viscera: this union depends principally on the subserous cellular texture, but partly on the vessels of these membranes. The firmness of the adhesion is not every where the same; in many places it is so inconsiderable, that a separation can be readily effected, as between the peritoneum and the muscles of the abdomen, or between the pleura and the walls of the chest, but the visceral layer is so closely attached that some care is required in raising it from the subjacent organ. The connexion is still more strict between the serous membranes and the fibrous structures; thus it is extremely difficult to separate the tunica arachnoidea from the dura mater, the reflected portion of the pericardium from the fibrous structure which strengthens it, or the tunica vaginalis testis from the tunica albuginea.

The free surface, which is polished and moistened by a thin fluid, gives to the viscera that shining appearance by which they are characterized, and which is so remarkable, that the limits of the serous membrane may be distinguished on any organ, as the urinary bladder, by the extent of this polish. It has been stated in a previous part of this chapter, that the free surface insulates the organs which are placed in juxta position with each other, as the stomach and the liver; and also that it facilitates in an especial manner, the movements of the parts which are provided with such a covering.

SECTION II.

ORGANIZATION.

THESE membranes are essentially composed of condensed cellular tissue, into which substance they may be reduced by maceration. Each of them is formed of one layer, the texture of which is very close towards the internal surface, whilst externally it becomes loose and flocculent, and is confounded with the cellular membrane, by which it is attached to the surrounding parts.

The peritoneum and the pleura appear to contain an immense number of vessels, which are so minute that they do not ordinarily admit the coloured part of the blood. They are rendered apparent by injection, and particularly by inflammation. It is necessary, however, to distinguish the vessels of the subserous cellular tissue from those of the membrane itself; the former are very numerous, and as they admit the red particles, they are readily perceived through the transparent serous membrane. The vascularity of these organs, and especially of the tunica arachnoides, has been denied by Rudolphi, Ribes, and others, who state that no vestige of vessels can be discovered by the microscope in the substance of the serous tissue. I had an opportunity, about two years since, of examining the arachnoid in an extremely opake and thickened condition. After the arteries of the brain had been filled with a fine injection, a great number of vessels were perceived, apparently ramifying in the membrane; but, on a careful inspection, it was evident that most of them were placed in the opake matter which was effused between the arachnoid tunic and the pia mater, so that I could not satisfactorily determine if any arteries penetrated into the former membrane. I am, however, inclined to admit the existence of vessels, because it is difficult otherwise to account for the production of the opacity, and other morbid changes of structure, which are so frequently observed in the tunica arachnoides, the pleura, &c. The presence of lymphatics is indicated by the active absorption which is constantly going on in the serous membranes. No nerves have been traced into the thickness of these structures, and they possess little or no sensibility during health, although they become painful under disease; but it is probable that the principal part of the severe pain which is experienced in peritonitis, &c. should be referred to the pressure which these membranes, in consequence of the strictness of their adhesion, exert on the subjacent parts.

The serous membranes, when they are dried, become yellowish; and if they were previously opake, they are rendered transparent. Maceration in water restores them to their former appearance; and if it be continued, it makes them soft, opake, and pulpy, and eventually it dissolves them.

SECTION III.

PROPERTIES AND FUNCTIONS.

THE splanchnic membranes possess the physical and vital properties which characterize the serous system in general.[*]

Their internal surface secretes an albuminous fluid which is very similar to the serum of the blood. It is generally supposed by anatomists that this fluid is separated from the blood in a gaseous form; but M. Magendie has discovered that a small quantity of watery liquid is contained in the tunica arachnoides of living and healthy animals.

The fluid secreted by the peritoneum, pleura, and pericardium, was carefully examined by Hewson, who states, that if it be removed from the body of a healthy animal recently killed, and be then exposed to the air, it will jelly like the coagulable lymph of the blood.[†] A similar opinion had been previously entertained by Lower, Lancisi, &c. The coagulation of this fluid has been denied by many anatomists; but I believe that it is always capable of coagulation in a healthy state, although in disease its qualities being altered, it is not concreted when exposed to the air, or even to heat. Dr. Bostock found that the serous secretion in health, contained water, albumen, but in a less proportion than the serum of the blood, some salts, and an incoagulable matter; the latter appears to be similar to the serosity of the blood.

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[*] See p. 149.

[†] Experim. Inquiries, part ii. p. 103.

Analysis of the liquor Pericardii :*—

Water	92·0
Albumen	5·5
Mucus	2·0
Muriate of Soda	0·5
	100·0

Fluid of Spina Bifida :†—

Water	97·8
Muriate of Soda	1·0
Albumen	0.5
Mucus	0·5
Gelatine	0·2
Lime, a trace.	
	100·0

Fluid of Hydrocephalus Internus :‡—

Water	988·3
Albumen	1·66
Muriate of Potassa and Soda	7·09
Lactate of Soda and Animal Matter	2·32
Soda	0·28
Animal Matter soluble only in Water, with a trace of Phosphates	0·35
	1000·00

The fluid contained in the amnios varies in different animals. That of the human female contains a large

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[*] Dr. Bostock, in Nicholson's Journ. vol. xiv. p. 147.

[†] Ibid.

[‡] Berzelius, in Med. Chir. Trans. vol. iii. p. 252.

quantity of water, a small proportion of albumen, soda, muriate of soda, phosphate and carbonate of lime, and a matter like curd, which gives it a milky appearance.

The principal use of the splanchnic serous membranes is to favour the movements of the viscera of the head, chest, and abdomen; they also insulate the contiguous organs, and, by attaching them to the surrounding parts, they act as ligaments; in many places they convey the vessels and nerves to their destination; and, lastly, around the stomach, intestines, &c. they contribute to the formation of those organs, by giving them an external tunic.

CHAPTER THIRD.

OF THE CUTANEOUS SYSTEM.

THE cutaneous system, *systema cutaneum*, consists of those membranes which cover the exterior of the body, and which line its internal passages; they are totally different from the serous membranes, in consequence of having external communications, and of being continually exposed to the contact of foreign bodies. This system comprehends two great divisions: 1. The skin or common integuments. 2. The mucous membranes. The differences which are observed in the appearance of these two structures are so considerable, that many authors describe them as separate and distinct textures; but a careful investigation of the human organization, assisted by the researches of comparative anatomy, has induced the highest authorities of the present day to regard them as belonging essentially to the same class of organs. The grounds upon which this opinion is supported, will be considered hereafter.

The following is an enumeration of the different parts which constitute this system.

I. The external cutaneous system, consisting of the skin and its appendages.

II. The internal cutaneous system, including,

a. The mucous membrane of the alimentary canal, which, commencing at the mouth, lines the digestive tube, and sends processes along the numerous excretory ducts which open on its surface, and ultimately ends at the anus.

b. The membrane of the pulmonary passages, which extends into the most minute ramifications of the bronchi.

c. The genito-urinary mucous membrane; this passes into the cavities of all the organs of generation, and of the secretion and excretion of urine.

d. The membrane of the nasal fossæ, which is also reflected into the sinuses of the bones of the head.

e. The small process which lines the Eustachian passage, the tympanum, and the mastoid cells.

f. The membrane which covers the external surface of the eye, and the inner part of the lids; viz. the tunica conjunctiva.

g. In the female, the processes connected with the ducts of the mammary glands.

In accordance with the plan that has been adopted in this work, I shall in the first place consider those properties which are common to both the divisions of this system, and subsequently I shall proceed to the separate description of the skin, and of the mucous membranes.

PART FIRST.

SECTION I.

OF THE CUTANEOUS SYSTEM IN GENERAL.

THE membranes of the cutaneous system are generally disposed in the form of ramifying canals, which, with the exception of the lining of the alimentary passage, ultimately end in blind extremities, or culs de sac. This form does not immediately strike the mind, because the mucous membranes are usually arranged in a very complicated manner; but if any one of their processes be carefully traced, it becomes apparent; thus, if the hepatic duct be followed into the substance of the liver, it will be perceived that its lining membrane at length terminates in a closed extremity. The external integument has, strictly speaking, a similar configuration in many parts of its extent; this may be seen in the cul de sac of the skin which encloses the end of each of the fingers and toes.

The two great divisions of the cutaneous system are continuous with each other at all the natural openings of the body, viz. at the mouth, the nostrils, the aperture of the eyelids, and at the commencement of the urinary and genital passages. The skin and the mucous membrane, although they are in such direct communication with each other, are dissimilar in their external appearance; and this circumstance has had considerable influence in inducing many anatomists to doubt the identity of their composition. But this is a very insufficient objection to support the conclusion that has been drawn from it; for, if similarity in appearance were required as the proof of the identity of structure, the most serious errors would be committed. If such reasoning were admitted, no one, for example, could believe, what is certainly true, that the delicate arachnoid of the ventricles and the coarse peritoneum of the loins, are both specimens belonging to the same class of membranes. It is necessary, then, to seek for other sources of information in order to determine the point in question. The first may be derived from an examination of the embryo in the early period of its existence, at which time there is so little difference between the external and the internal integument, that they are distinguished from each other with difficulty. The perfect continuity of the skin at the external apertures of the body with the internal membranes, is another proof which supports the opinion of these structures being identical. At the lips, at the nostrils, at the eyelids, at the anus, at the meatus urinarius, at the labia pudendi, we see the skin gradually changed into the mucous membrane. It is true, that around some of these openings a slight line of demarcation exists, as at the tarsal edge of the eyelids and at the lips; and a similar appearance may be more evidently observed in some of the internal parts of the body, which are contiguous with each other but distinct in function; as for example, where the cuticular lining of the œsophagus joins with the villous tunic of the stomach, and, in a less degree, in the connexion between the inner membrane of the vagina and the vascular coat of the uterus. But these distinctions do not extend to the *structure* of the two divisions of the cutaneous system, and therefore it cannot, with any truth, be asserted, that one is not perfectly continuous with the other.

The organization of the animals which are placed lowest in the scale, displays, in a striking manner, the resemblance of the external and internal coverings of the body; in these creatures there are none of those diversities of appearance that have given rise to so much uncertainty in the human subject; the skin and the mucous membrane are, in fact, so completely identical, that one may, with impunity, be substituted for the other; so that if the polypus be turned inside-out, the new internal surface acquires the power of digestion, and the new external surface that of protecting the body. The effects of certain diseases, as for example, the prolapsus uteri and the prolapsus ani, occasionally shew that the mucous coat of the internal organs may become so altered by exposure to the air, as to assume in time some of the characters of skin.

We may then, I think, safely conclude from the preceding observations, that the differences which exist between the two great divisions of the cutaneous system, relate principally, though not entirely, to their external appearance. These diversities not only characterize the skin and the mucous membrane, but also their individual parts, as may be seen by comparing the skin in the palm with that of the dorsum of the hand, or the skin of the scalp with that of the fingers. The differences are still more apparent in the mucous membranes; of the truth of this statement we may satisfy ourselves by comparing the lining of the frontal sinuses with that of the stomach, or even with the proper Schneiderian membrane.

In the places where the skin and mucous membranes are continuous with each other, the former becomes more thin and smooth, and its tissue more delicate. According to Bichat, the limits between them are indicated by a reddish line; this may be traced on the lips, but at the other openings the change in appearance is so gradual, that no distinct separation can be observed.

The disposition of the cutaneous system is such, that it possesses two surfaces; one of which is free, and the other adherent. In the skin, the former is placed externally, and the latter internally. In the mucous membranes, it is said that the arrangement is reversed; but strictly speaking, in the stomach, the intestines, &c. the free surface is still situated externally as regards the passage of foreign substances.

The adherent surface is united to the substance of the body by the subcutaneous and the submucous cellular tissue, the quantity and density of which are liable to great variation. The internal portion of the cutaneous system is generally in immediate relation with the involuntary or hollow muscles; but the external portion is, in most parts of the body, separated from the muscles of volition by a strong fascia or aponeurosis.

The free surface possesses a much more intricate and important organization than that which adheres. This complicated structure is provided for the defence of the cutaneous texture against the action of foreign bodies, and for the performance of its extremely numerous and diversified functions. In all parts of this surface, numerous small depressions are furnished, which have been named by some writers according to their situation and the fluid they secrete, simple glands, sebaceous glands, and mucous glands; by other anatomists they are called follicles, lacunæ, cryptæ, &c. These minute bodies exist in every part of the cutaneous system; they vary in size, and also in shape, some being round, and others oblong or infundibular. Each of them is formed by a fold of the entire membrane, having the form of a cul de sac, the mouth of which is the duct of the follicle and conveys its secretion to the free surface. The openings of the follicles are very evident in some places, as on the skin of the nose, where they appear like dark grey spots; in the mucous membrane, on the contrary, the microscope is required to bring them into view. The number and disposition of these bodies is subject to great variation; in some parts, although they are very numerous, they are distinct from each other; this is the arrangement in the skin and in some of the mucous membranes; in other parts they are clustered together, as in the formation of the tonsils, &c. The follicles are supplied by many vessels which are derived from those of the integuments.

This free surface, especially in the mucous structures, presents a great number of wrinkles and folds, which are of a very different character according to the part in which they are placed; some of them are permanent; whilst many among them are temporary, existing or not, as the organ containing them is empty or distended.

SECTION II.

ORGANIZATION OF THE CUTANEOUS SYSTEM.

THIS system consists of certain layers superposed on each other; they are so different in their structure, that they might almost be considered as so many separate systems, if it were not preferable to regard them only as so many parts of the same system. The number of these layers varies in the skin and mucous membranes; in the former, three are generally enumerated, the dermis, the rete mucosum of Malpighi, and the epidermis; the latter consist essentially of one layer only, the mucous corium or dermis. Meckel describes, as a fourth lamina, the textus papillaris, which is, apparently, only a portion of the dermoid texture.

The dermis, which is the most deep-seated and solid layer, is united in all its extent to the subjacent structures, and thus gives support to the other parts of the cutaneous system. It is whitish, soft, and elastic, and is composed of a fibrous layer of cellular tissue, which varies in its thickness and density. It receives a great number of vessels and nerves which are placed on its external surface, where they form a delicate structure consisting of the minute divisions of arteries, veins, lymphatics, and nerves; from this important fabric numerous minute bodies project, which are called nervous or vascular papillæ.

The rete or corpus mucosum, which is only met with in the skin, consists of a very soft and delicate substance interposed between the dermis and the epidermis. It receives the termination of a great number of sanguineous capillaries, and lodges the commencement of many lymphatics. It is the seat of the colouring matter, and, according to some anatomists, of those horny processes which are attached to some parts of the cutaneous organ.

The epidermis forms the most external part of the skin and of some of the mucous membranes; it is whitish, solid, and apparently destitute of vessels and nerves. It is considered by many writers as being an inorganic concretion, but for reasons which will afterwards be advanced, I am inclined to admit it as one of the organized solids. It is essential to the protection of the body against the injurious influence of external agents, which immediately cause irritation in any part of the surface where it may have been accidentally detached. It is equally necessary for the preservation of animals and vegetables, forming in both, as it has been well observed, a fine but essential barrier between life and destruction. The epidermis cannot be traced in the majority of the mucous membranes, in which the constant secretion of a mucous fluid appears to supply its place.

The chemical composition of the cutaneous system, notwithstanding the attention which has been paid to it, is not yet perfectly understood. The best English and French chemists describe the cutis as consisting chiefly of jelly. Dr. Bostock thinks, that the fibrous part of the skin, which forms its proper substance or basis, is composed of albumen, and that it has, intermixed with it, a quantity of matter of a different chemical nature, which he supposes to be a compound of jelly and mucus.

SECTION III.

PROPERTIES AND FUNCTIONS.

THE properties of the cutaneous system, like those of membranous structures in general, are almost entirely of a physical character. The colour of the skin and mucous membranes is different; and in both, but especially in the former, it is liable to many variations. The colour depends, in part, on that of the blood, and in part on a colouring matter which is secreted from that fluid. The seat of this substance in the skin, is the corpus mucosum; its appearance varies, not only according to the different varieties of mankind, but also in individuals of the same race, country, or even family. In the mucous membranes there is more uniformity, the colour generally being light yellow, often tinged with red or brown.

The density of this system, which is greater in the skin than in the mucous membrane, is very considerable; it exceeds that of the cellular tissue, but it is less than that of the ligamentous organs.

The extensibility and flexibility of the cutaneous membranes are very great; in the skin, these properties allow of the varied movements of the body being performed without any risk of laceration; in the mucous membranes they admit of the change in size which is so frequently required in the hollow viscera, as in the stomach, the intestines, the urinary bladder, &c.; the alteration in the volume of these organs partly depends, however, on the unfolding of the rugæ which exist on their internal surface when they are collapsed.

The contractility, or, as it has been called, the tone of these structures, is very much developed. It is occasionally exerted with great rapidity, as when the mouth suddenly contracts on the air or food which it contains. Generally, however, the contraction takes place slowly, and often to a great extent; thus the lining membrane of the uterus, after delivery, gradually retracts to its original size, and again in the permanent artificial anus, the inferior portion of the intestine is so much diminished in its calibre, that the colon is occasionally reduced to the size of the finger. The contractility of the skin, although considerable, is inferior to that of the mucous membrane; it is known, for example, that in the removal of a large tumour from the surface of the body, if a sufficient quantity of the integument be not taken away the skin is afterwards loose and wrinkled, and a similar appearance is observed on the lower part of the abdomen in women who have borne several children.

Some anatomists have admitted, that the integuments are irritable, or, in other words, that they contract on the application of a stimulus; this opinion is, I believe, altogether erroneous; for, as far as I have had an opportunity of observing, the skin and the mucous membranes when they are irritated in a living animal, exhibit no proofs of contraction independent of that which is caused by the action of the subjacent muscles.

The sensibility which these parts possess, is their most remarkable property, and enables them to fulfil their important offices in the economy. In the skin it is very manifest, for it is in this organ that the sense of touch is exercised. Many parts of the mucous tissue are endowed with a high degree of sensibility; thus two of the special sensations, viz. smelling and tasting, reside in the commencement of the extended membrane which lines the digestive and pulmonary organs. Again, the surface of the glans penis, and of the urethra in the male, and of the vagina in the female, possess an exquisite sensibility which is greatly excited during coition. In most parts of the mucous membranes there is, however, only that obscure kind of sensibility which enables them to receive the different impressions of the foreign substances that are brought into contact with them; it is necessary to add, that these impressions are never perceived by the mind, in the healthy state of the organs, although in disease the natural stimulants, as the food in the stomach and the urine in the bladder, will excite the most painful sensations.

The functions of the cutaneous system, which are extremely complicated and diversified, are very important, and immediately connected with the support of life.

The most universal and essential use of the external integument, is to protect the body against the decomposing and destructive influence of chemical agents, which instantly exert their power wherever this defensive covering is removed. In man, and in a less degree in the higher classes of animals, the skin is an exquisitely sensitive organ, which assists to establish their relations with the external world, by receiving the impressions of the innumerable bodies that surround them. The mucous membrane is equally a defence to the internal organs; it constitutes a barrier through which all foreign substances must pass in order to enter into, and to form part of, the body; and at the same time no substance which has for a certain period constituted a part of the body, can pass from it, but through the medium of the mucous membrane, or of the skin.

The free surface of the tegumentary system is a most extensive organ of secretion and absorption. There are two distinct secretions performed by the skin; one is derived from the sebaceous glands or follicles, and the other from the minute termination of the arteries. The first secretion defends the skin from the influence of the foreign bodies by which it is surrounded; the second purifies the blood, and also assists in regulating the animal temperature. The mucous membrane has likewise two secretions; one consisting of a mucus, which is provided for the protection of these structures against the contact of foreign substances; and the other, composed of a vapoury halitus, somewhat similar to the perspiration of the skin, has probably the same use as that fluid, as far as purifying the blood is concerned. The absorbing powers of the skin and mucous membranes are very considerable, and of great importance in the economy. The further consideration of these processes is deferred, till the properties of the two divisions of this system have been more fully investigated.

The preceding sketch proves that the cutaneous apparatus is provided, both externally and internally, for the defence of the animal body; that it is the seat of several of those functions by which the individual is connected with the external world; and, lastly, that it is the medium by which all extrinsic secretion and all external absorption are effected.

The most cursory review of the facts which have been considered in this chapter, will be sufficient to explain the immense importance of the cutaneous system in the operations of the animal economy. We have just stated how necessary the functions of this system are for the support of life; if any one of them were suspended, even for a very short period, death would be the inevitable result. The cutaneous membranes, connected as they are with the outer surface of the body, with the organs of digestion, of respiration, of the secretion of urine, and of generation, constitute a common bond between the vital functions, a perfect knowledge of which is of the first consequence in the study of health or of disease. The sympathies which are thus established, and which have been long observed, are frequently very evident; especially those which exist between the skin and the lungs, the skin and the stomach, and the skin and the kidneys.

SECTION IV.

DEVELOPMENT OF THE CUTANEOUS SYSTEM.

THE embryo appears, in the beginning, to be entirely composed of the skin and mucous membrane. A communication exists at an early period after conception, between the vesicula umbilicalis and the interior of the alimentary canal; and many writers, particularly Dutrochet, suppose that there is a similar connexion between the allantois and the urinary bladder.* At this time the anterior part of the body and also the intestinal tube are open, so that there is a complete continuity between the internal and external membranes. Afterwards, the walls of the intestine unite so as to form the canal; and the skin begins to close on itself, and at length its lateral halves coalesce on the median line, which retains, even to the termination of life, several indications of the original division, such as the raphé of the scrotum, of the perineum, &c.

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* See p. 79.

The mucous surface of the intestines is more simple in the fœtus than it is subsequently, in consequence of the absence of the convolutions and of the valvulæ conniventes; these folds begin to appear towards the end of pregnancy. The organization is also defective, owing to the vessels and nerves being few in number, and the skin and mucous membrane being thinner than they are after birth. The sebaceous follicles are observed to be very much developed towards the sixth month, and at this period the body of the fœtus begins to be covered with a caseous and greasy substance, by which it is defended from the contact of the liquor amnii. A quantity of viscid fluid is also met with in the intestines, which has at first a whitish and mucous appearance, but afterwards it becomes dark coloured and greenish; it is called the *meconium*.

Erroneous ideas have prevailed amongst some writers concerning the source of these two substances. According to these opinions, the curdy matter which covers the skin is deposited from the liquor amnii; and the meconium is supposed to be the residue of the amniotic fluid, which has been swallowed and digested in the stomach. There can be no doubt, however, that the above substances are respectively secreted by the sebaceous and mucous follicles.

The cutaneous system does not exhibit any very remarkable changes in the advance of life, excepting that the skin loses some part of its elasticity, and thus becomes loose and wrinkled on its surface, and also that the activity of its secreting and absorbing powers is rather diminished.

PART SECOND.

OF THE SKIN.

The skin, or external integument, forms the outer covering of the body, connecting its different parts together, and defending the entire structure from the influence of external agents. All animals are provided with such a covering, although its properties and appearance are liable to great variation.

The skin in the human species, is extremely complex in its organization; it consists of distinct layers, each of which has a texture proper to itself, and exercises peculiar functions. The number of these laminæ has been variously estimated, but the majority of anatomists admit three, viz. the cuticle or epidermis; the rete or corpus mucosum; and the cutis vera, the dermis, or corium. The existence of the rete mucosum as a proper membrane, has been doubted by many high authorities, although there are not wanting others who have adopted the opinion of Malpighi; the consideration of this question is deferred till the rete mucosum is described. In addition to the preceding parts, there are certain appendages which belong to the cutaneous organ of the human subject; viz. the nails and the hairs.

The skin has an external and an internal surface. The former, which is free and unattached, is in contact with the atmosphere, and presents several objects for examination. On all parts of its extent, furrows and wrinkles are perceptible; in other places minute spots or openings are seen, and some anatomists have also thought, that small pores exist, although, from their minuteness, it is difficult to demonstrate them.

The furrows of the skin are either proper to its texture or are produced by accidental circumstances. The former are met with on most parts of the outer surface; but they are particularly distinct in the hand and foot; in the palm of the hand they have a curvilinear arrangement; whilst on the dorsum they intersect each other so as to describe figures of various shapes. A similar disposition is observed, but less perfectly, in the foot. In those parts of the body where there is considerable motion, numerous folds are formed, in consequence of the inability of the skin to contract; such, for example, are the furrows formed opposite to the different joints of the toes and fingers; and the wrinkles of the palm of the hands, of the eyelids, the forehead, the neck, the anus, &c. It is well known in old age the number of wrinkles is greatly increased, in consequence of the skin being then deprived of its tone, and the subcutaneous fat being absorbed. The existence of pores on the external surface of the skin, independently of the ducts of the sebaceous follicles and of the holes which give passage to the hairs, is very doubtful, although there must be some passages for the transmission of the perspirable matter. In the last place, it may be mentioned, that this surface is covered with innumerable hairs, and is constantly moistened by the secretion of the sebaceous follicles, and of the cutaneous arteries.

The internal or the adherent surface of the skin is totally different in its appearance from the outer; it is looser in texture, and is gradually confounded with the subjacent cellular tissue, with which it is, in all its extent, in contact. This tissue is generally lax, and thus loosely connects the skin with the parts beneath, so as to allow the varied movements of the body; in some regions, being rather more condensed, it fixes the skin more closely, as on the scalp, and on the median line of the abdomen. In other places there is a fibrous connexion between the inner surface of the skin and the parts below; this is seen around the wrist, in the palm of the hand, and in the sole of the foot. In quadrupeds the integument is joined to a fleshy layer, called panniculus carnosus; but in man there is no such structure, except on the scalp, on the face, and on the neck. Bichat has described a number of depressions on the inner surface of the skin, which, being apparent to the naked eye, give it an areolated appearance, when the cellular tissue is removed by dissection.

SECTION I.

OF THE EPIDERMIS.

THE epidermis, called also the cuticle or scarf skin, is the most external layer of the skin; it is, with a few exceptions, transparent, and of a greyish white tinge, and thus allows the colour of the parts beneath it to be seen. In the dark races of mankind, the cuticle is imbued with the colouring matter of the corpus mucosum. It is in most parts of the body thin and delicate, having in general, according to Dr. Gordon, about the one-fifth or one-sixth part of the thickness of the true skin, which it covers. The thickness is greatly increased by continued pressure, provided it be not too suddenly applied; thus the cuticle is very thick on the heel, and ball of the great toe, and in those mechanics who employ the hands in laborious occupations, the epidermis becomes hard, thick, and even horny. But if the skin be too much or too quickly excited, instead of being thickened, it is irritated, and the vessels beneath throw out a quantity of serous fluid, which raises the cuticle and forms a blister. Independently of the effects which are produced by mechanical pressure, the cuticle exhibits differences that exist in the fœtus; it is thicker for example in the palm of the hand and in the sole of the foot, than in the other regions of the body.

Some anatomists, and among others, Blumenbach, state that the cuticle can be separated into several laminæ; but this can only be accomplished in those places where it has been compressed, for in its usual condition not the slightest appearance can be discovered of laminæ or fibres.* It is also very flexible, and so yielding in texture, that it readily tears.

The epidermis is the most extended membrane of the skin, for it not only covers the exterior of the body, but it is also reflected into all those openings which are formed on its surface; and after lining to a certain extent the passages that lead from them, it either again becomes continuous with the cuticle, or is confounded more or less abruptly with the mucous membrane. Thus it is reflected over the eyelids and anterior part of the eyeball; it lines the external auditory canal, the nostrils, the mouth, the tympanum, and the pharynx; from the last it is continued along the œsophagus to the stomach, and by the trachea to the lungs; it also extends into the anus, the vagina, and the urethra. In fact, the cuticle, and the structure that is analogous with it in the mucous membranes, cover all those parts of the body which are exposed to the contact of the air, or of foreign bodies. This was observed by Haller, who said that he knew no part of the human body which could be exposed to the air with impunity, except the cuticle and the enamel of the teeth.

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* Gordon, Syst. of Anat. p. 237.

The external surface of the epidermis, which is also that of the skin, presents, as we have already stated, innumerable wrinkles, most of which are proper to the structure of the skin. These have been well described by the late Mr. Chevalier, to whose scientific work* I am indebted for much valuable information. The two most striking variations in the disposition of the rugæ, are seen in the hand. On the palmar extremities of the fingers and thumb, and less perfectly in the palm itself, the cuticle presents a curvilinear appearance; whereas on the dorsal side, the rugæ pass in various directions, longitudinally, transversely and angularly. The arrangement on the palmar extremities of the fingers, where the epidermis is stretched over the cutis vera from one side of the nail to the other, is evidently intended to preserve that degree of tenseness in the subjacent skin, which is essential to the nicest exactitude and delicacy of the organ of touch. The rugæ that appear in other parts of the cuticular surface, are adapted to the greater mobility which is there required; they also mark out lines, at which a kind of ligamentous structure descends to the coriaceous part of the skin, which keeps the whole organ steady in the varied movements of the body; this admirable mechanism prevents rigidity, and admits of yielding without the risk of laceration.

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* Lectures on the General Structure of the Human Body, and on the Anatomy and Functions of the Skin.

The internal or adherent surface of the epidermis, is so intimately united to the skin, that it cannot be separated by dissection; but it is readily detached by the process of putrefaction, by maceration, the application of heat, and by stimulating substances. The inner surface presents an appearance precisely the reverse of the outer, and also of the outer surface of the true skin, to which it is applied. When the cuticle is raised from the layer beneath, most of the hairs are extracted with it, but some still remain attached to the cutis. If this separation be accomplished by putrefaction, a number of very delicate, transparent, and colourless filaments are observed, which admit of some extension before they give way. These threads were described by Dr. W. Hunter, who supposed they were the vessels which secrete the sweat. Bichat and Chaussier regarded them as consisting of exhalants and absorbents. There is considerable uncertainty as to the real nature of these filaments, as many anatomists deny that they are vessels. Cruikshank thought they were exceedingly fine processes of the cuticle, which lined the smallest pores of the dermis. Meckel conjectures that they may result from the action of heat, in those instances where the epidermis is detached by plunging the skin into boiling water. Dr. Gordon conceives that they are merely threads of the pulpy matter which is always formed between the cuticle and true skin after death, in consequence of decomposition. I am inclined so far to agree with this distinguished anatomist, as to admit that most of the filaments are produced by the traction of the above mentioned pulp, but I believe that there are mixed with them a considerable number of minute vessels.

Many investigations have been made in order to ascertain if the cuticle possesses any pores for the transmission of the perspiration, and of the various substances which are absorbed by the skin. Leeuwenhoek thought he had seen them; and more recently Bichat, who has endeavoured to prove their existence, states that if a portion of epidermis be examined in a favourable light, an immense number of pores are observed crossing its thickness in an oblique direction. Most anatomists, however, confess their inability to detect these passages. Cruikshank and Gordon agree in stating, that when the most powerful magnifying powers are employed, no pores can be distinguished. They assert, that in a separated piece of cuticle not the least vestige can be traced of the openings by which the hairs perforated it, nor of those by which the sebaceous ducts opened on its surface. These observations do not prove that there are no pores; for they might have originally existed, although they could not be seen in the detached cuticle, on account of being closed by its elasticity.* Mr. Chevalier, whose remarks are well worthy of attention, says that, although he examined with the microscope, cuticle taken from different parts, he could perceive no openings deserving the name of pores, except where it was evident small hairs had made perforations. Instead of pores, he found an infinite number of minute velamina, regularly arranged, so as to form a bibulous and exquisitely hygrometrical covering, in which the terminal vessels are lodged, and through which, during life, the processes of exhalation and absorption are safely and perfectly effected.

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* Cruikshank, Experiments on the Insensible Perspiration, p. 13.

Although no pores can be satisfactorily demonstrated, yet the arguments by which Cruikshank endeavours to prove their existence, are very forcible; and shew, that whatever may be the process by which the sweat is transmitted to the surface of the body, it is something different from the mere transudation by which fluids soak through dead animal or vegetable substances.*

The opinions of anatomists respecting the formation of the cuticle, are uncertain and contradictory. It has been supposed by some writers, that it is originally formed by the hardening of the surface of the skin, which is accomplished before birth by the pressure of the liquor amnii, and afterwards by that of the atmosphere. This hypothesis is certainly erroneous, for as the compression exerted upon the body before and after birth is uniform in all parts, the epidermis, according to this explanation, ought to be of an equal thickness throughout; but we find on the contrary, that even in the fœtus some portions are thicker than others, according to the office they are destined to fulfil.

Many anatomists regard the cuticle as an inorganic concretion, which is exuded on the surface of the skin; and which, being constantly renewed, is destroyed on the exterior in proportion as it is produced from the interior. Notwithstanding that it is insensible, and that no blood-vessels, absorbents, or nerves, have ever been satisfactorily traced to it, still there appear to be sufficient proofs that it is, like all the other parts of the living body, an organized substance. I have myself arrived at this conclusion, principally from reflecting on the well-ascertained fact, that no inorganic substance can be intimately attached to a living part, without exciting irritation and an attempt of nature to cause a separation between them. Now the epidermis is so closely united to the sensible cutis, that it cannot be raised without the aid of chemical means; and yet this connexion produces no disturbance; on the contrary, there is such a mutual sympathy between the two parts, that many of the morbid changes of the one are attended with corresponding alterations in the condition of the other; for the skin and the cuticle are each dependent on the other for the perfection of their structure and the performance of their functions. If the cuticle were not organized, it would be impossible to explain the manner in which it is regenerated after it has been destroyed, or to account for those varieties which exist in the arrangement and texture of its different parts.

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* l. c. p. 12, *et seq.*

It is probable that the cuticle is vascular, and that its vessels are derived from those which ramify on the cutis vera, although on account of their minuteness, they cannot be detected. But if it could be demonstrated, which hitherto has not been done, that the cuticle is non-vascular, it would not, therefore, follow that it was unorganized.* No nerves have been traced to this substance, a fact which will explain its total insensibility.

The power of reproduction is greater in the cuticle than in any other of the organic solids; it is constantly in a state of growth and of decay; its exterior surface dying off in small scales in proportion as it is generated underneath. Leeuwenhoek erroneously supposed that these scales formed a part of the original structure of the epidermis; and some modern anatomists, adopting this error, speak of the squamæ of the cuticle. It is often cast off in larger pieces, in consequence of disease; in erysipelas, for example, the cuticle of the hand has been thrown off entire in the form of a glove; and a similar phenomenon has occurred in the foot.* When the epidermis is lost in such a large quantity, it is still very speedily restored, although it remains for a considerable time, and in some cases always, in an imperfect state; it often cracks and sooner dries; and it is also more liable to abrasion, and is more slowly renewed when abraded or blistered.

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* See p. 120.

The cuticle is nearly imputrescible, so that it resists decomposition for a very long time. Thus in tombs, which contain merely the dust of the skeleton, it is not unusual to find the thickened epidermis of the heel entire, and in a state readily to be distinguished.

When the cuticle is dried, it decreases in bulk, and becomes firmer, and rather yellow. If it be macerated in cold water, it swells a little, is rendered softer and less elastic, and acquires a considerable degree of whiteness and opacity; but these changes take place gradually, because the cuticle imbibes water very slowly. The action of boiling water renders the cuticle whiter and more opake, and deprives it of its elasticity more speedily than cold water. Prolonged ebullition separates a small quantity of gelatine, which is said to come from the inner surface. When the cuticle is exposed to a red heat, it burns like a piece of horn or feather, and emits a similar smell. The majority of chemists describe the cuticle as consisting principally of gelatine; but according to some high authorities in this country, concreted albumen enters largely into its composition. The following is an analysis of the human epidermis:—Concreted albumen, 93 to 95; Animal matter, soluble in water, 5·0; Fatty matter, 0·5; Lactic acid, lactate, phosphate and hydro-chlorate of potash, sulphate and phosphate of lime, an ammoniacal salt, and traces of iron, 1·0.*

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* Chevalier's Lectures, p. 122.

The properties of the epidermis are altogether of a physical character. It is very dense and compact, and thus powerfully assists in preserving the moisture of the skin and of the body in general; it is also flexible and capable of being considerably extended. But the most remarkable character of this membrane is its elasticity, which is so great that when it has been perforated with a fine needle the apertures are immediately closed, and consequently escape detection even when the microscope is employed.

The functions of the epidermis are so intimately connected with those of the skin in general, that only an imperfect account can be given of them in this place. Its most important use is to defend the body against the injurious influence of chemical and mechanical agents. It prevents the evaporation of the animal fluids in a very remarkable manner, so that a portion of dead skin, covered by the cuticle, may be exposed to the air for several weeks before it is dried; on the contrary, if the epidermis be removed, the cutis vera being deprived of its moisture, soon becomes dry, hard, and discoloured. It moderates the impressions which are made on the nervous papillæ of the true skin, and guarding these delicate structures from the irritating contact of foreign bodies, it preserves that exquisite sensibility which is necessary for the proper exercise of the sense of touch. The complicated processes of cutaneous secretion and absorption are effected through the appropriate structure of the epidermis; and, lastly, the hairs, the nails, and the sebaceous glands, are all kept by it in their proper situations and offices.

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* Richerand's Elem. of Phy. p. 695. John, Ecrits Chimic. vj. 92.

SECTION II.

OF THE RETE, OR CORPUS MUCOSUM.

THE second layer of the common integuments, *corpus mucosum et reticulare*, *rete vel reticulum Malpighianum*, was first discovered by Malpighi, in the tongue, and, subsequently, in the skin. He described it as consisting of a soft substance, placed between the epidermis and cutis, and arranged in the form of delicate fibres intercrossing with each other, so as to constitute a kind of network. Since his time, anatomists have been divided in opinion concerning the nature of this part, and some have even denied its existence as a distinct membrane; the majority, however, are decidedly in favour of Malpighi.

The mucous body has been most commonly examined in the African, in whom it is readily distinguished on account of its dark colour and thickness. Cruikshank, who carefully injected the skin of individuals who had died of smallpox, states, that he could separate no less than four membranes between the epidermis and cutis; the two external of which belong to the rete mucosum; the

the third, a vascular layer, in which the varioloid pustules were placed; and the fourth, a delicate membrane immediately covering the papillæ of the dermis.* Gaultier, whose description is nearly similar to the above, thinks he has demonstrated three layers in the rete mucosum of the Negro, the external and internal of which are white, whilst the middle lamina contains the colouring matter. This account appears to be adopted by Meckel, Beclard, Cloquet, &c.

Dr. Gordon states, that he has ascertained, by many dissections, that there is in the Negro, Caffre, and Malay, a black membrane interposed between the epidermis and the true skin, upon which the dark colour of these people entirely depends; and he concludes that the colour of black men, in general, is owing to a similar substance; but he denies its existence in the fair variety of mankind.

There are, however, several high authorities, who altogether deny the existence of the corpus mucosum; of this number are Bichat, Chaussier, and Rudòlphi. Some have said, that it is nothing more than a deep layer of the cuticle; and others, as Blumenbach, consider that it consists of a thin layer of pulpy matter, without any reticulated structure. Again, Bichat supposes that the substance described by Malpighi, is not a proper membrane, but that it consists of a network of extremely delicate vessels, placed on the outer surface of the true skin, and which contain fluids of various colours, according to the different races.

My own observations on this subject, have induced me to conclude, that there is a distinct membrane in the

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* Experiments on the Insen. Perspir. p. 44.

Negro, interposed between the cuticle and cutis; but I have not been able satisfactorily to separate a similar texture in the skin of white people. I am inclined to believe that such a substance does exist in Europeans, independently of the vascular plexus which covers the cutis vera. If this be not admitted, it would be difficult to explain the cause of the various shades that are seen in the fair races of mankind, or to account for the tanning which is produced by exposure to the sun; these effects must depend on the presence of some colouring matter, and it is more in accordance with analogy to suppose that it is lodged in a proper membrane, than that it is contained in the circulating vessels.

The rete mucosum, when it is investigated in the Negro, appears to consist of a delicate cellular tissue, which is very soft, and contains, as Malpighi first announced, a dark substance, giving colour to the skin. The corium, whatever may be the colour of the skin, is always white; it is sometimes a little tinged, but this is an accidental circumstance, apparently depending on the transudation which occurs after death, or from the adhesion of a small part of the rete mucosum; the epidermis is more affected by the colouring matter, so that in the Negro it has a greyish appearance.

There are five principal shades in the colour of the skin, corresponding to the races of mankind.* In the Caucasian variety it is more or less white, possessing, however, different tinges of red and olive; in the Mongolian, the skin is yellow, or resembling box-wood; in the Ethiopian, it is of a tawny or jet black; in the American, it is almost copper-coloured, and, in some instances, of a cinnamon, and, as it were, ferruginous hue; in the Malayan, it is tawny, between the hue of fresh mahogany and that of chesnuts. These various shades of colour run so insensibly into each other, that all division and classification of them must be more or less arbitrary.*

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* See p. 91.

In certain individuals the colouring matter is entirely deficient; such persons are called Albinos; the term originally being derived from the Portuguese, who applied it to some white Negroes whom they found on the coast of Africa. In Albinos there is not only a want of colour in the skin, but also in the hair and eyes; the former is of a milky whiteness, and in the latter, the iris and choroid are red. Blumenbach was the first who conjectured the real cause of these peculiarities; he conceived that the pink colour of the eye and its delicate sensibility depend on the absence of the pigmentum nigrum, the deficiency of which allows the great vascularity of the iris and choroid to be observed; this opinion has since been confirmed by actual dissection. Albinos are met with in all parts of the world, but they are more numerous among the natives of Africa and the Aborigines of America, than in the fair variety of mankind. Those found in the isthmus of Darien are even so numerous as to have given rise to the erroneous supposition, that they formed distinct tribes. The history of many Albinos proves, however, that the physical defect of organization, which is the cause of their variety, may be transmitted to their offspring, and thus become hereditary.

The rete mucosum presents no appearance of openings, although some must exist for the passage of the hairs and for the ducts of the sebaceous follicles. It possesses a great number of depressions, which receive the nervous papillæ of the true skin, furnishing to each of them a delicate sheath; these sheaths will yield considerably when the papillæ are elongated by disease, before they rupture or become perforated by them. This structure, according to the observation of Mr. Chevalier, is more closely connected with the sebaceous follicles than the cuticle is; so that when it is detached from the dermis, many of those little bodies are removed with it.

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* Blumenbach's Physiology, by Elliotson, p. 175.

The vascularity of this second layer of the skin, has never been proved by injection; in fact, Gordon considers it as perfectly inorganized, and Bichat says, it possesses no circulation. The reasons which have been adduced to show the probability of vessels passing to the epidermis, may be applied, and with more force, to prove the same with respect to the rete mucosum. The colouring matter is most likely deposited from the arteries, although it has been said that it is derived simply by imbibition. No nerves can be traced; but Gall assimilates this texture to the grey matter of the brain.

The mucous body is capable of reproduction, but not so extensively as the cuticle. A contrary opinion has prevailed in consequence of the common statement that the cicatrices of Negroes always continue pale; but Meckel and Gordon assert that the scars of wounds, and the marks of smallpox, or of ulcers of any kind, in black people, so far from remaining white, uniformly become blacker than the other parts of the skin. I have lately examined a Negro who had three cicatrices on one of his legs, all caused by incised wounds. Two of them were decidedly lighter than the surrounding skin, but the third was as dark, if not darker.

The rete mucosum is considered by Mr. Chevalier as a second or internal epidermis, which serves as a delicate intermedium between the insensible cuticle and the vascular and nervous substance of the true skin; thus preserving the sensibility of the latter, and securing the regular performance of its numerous functions. It is also connected with the regulation of the temperature of the body, for it is itself a bad conductor of heat, and being placed immediately under another bad conductor and over a quick one, it must materially contribute to the uniformity of temperature, so necessary to an animal who is destined to inhabit all climates. The dark colour of the network of Malpighi in the African, has been for a long time considered as a provision of nature for the defence of the skin against the powerful effects of a tropical sun. This opinion is rendered more probable by the experiments of Sir E. Home. This distinguished physiologist ascertained that by tightly binding a piece of *black* kerseymere around his arm, a temperature, which burned off the nap of the cloth, produced no painful effect on the skin, although it was applied for fifteen minutes; on the contrary, when a piece of *white* kerseymere was similarly placed on the arm, a less degree of heat caused a blister in fifteen minutes. Sir Everard also found, that a temperature which excited pain and irritation in his own skin, produced none in the skin of a Negro.* We learn, however, from the observations of travellers, that the colour of the skin is not constantly in relation to the climate; but on the contrary, that there are dark races of people who inhabit the coldest regions, and light nations who live in the warmest climates; it is also known, that tribes entirely differing from each other in colour, inhabit the same latitude, and even the same islands.* Mr. C. Bell denies that the black skin preserves the Negro from the great heat of the African climate; he rests his opinion on the experiments of Priestley, which prove, that a dark body absorbs light and heat more rapidly than a white one, which repels them. But we should recollect that a high temperature irritates the skin, in consequence of acting on the surface of the cutis vera, and not on the rete mucosum, which is insensible. Now it is evident, that the latter, by absorbing the heat, prevents its action on the true skin; whilst in a white individual the heat passes through the semitransparent epidermis and rete Malpighi, and thus acts immediately on the sensitive surface of the cutis. In support of Sir E. Home's theory, it may be mentioned, that Europeans who are exposed to the direct rays of the sun in hot countries, suffer severely from the irritation of the skin; at the same time that the dark inhabitants of these climates expose their naked bodies with perfect impunity.† The phenomena connected with the colour of the skin in different parts of the world, are, however, so very contradictory, that with our present information, it is impossible to arrive at any satisfactory conclusion respecting them.

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* Phil. Trans. for 1821, p. 1, *et seq.*

The colouring matter can in part be removed by prolonged maceration in water. The same effect can be more speedily produced by a solution of chlorine;

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* Dr. Prichard, Phy. Hist. of Mankind, vol. i. pp. 457 and 489.

† The above difference ought partly to be attributed to the much greater activity with which all the cutaneous functions are performed in the Negro.

thus a Negro, by keeping his foot for some time in water impregnated with that gas, deprived it of its colour, and rendered it nearly white. The dark matter which is separated by maceration, is first diffused in the water, and subsequently is deposited as a brown impalpable powder. According to Blumenbach, the essential cause of the colour of the mucous body is the proportion of carbon that is excreted together with hydrogen from the corium, and which, in dark nations, being very copious, is precipitated, and combined with this body. This statement has been confirmed by the investigations of Davy and others. Beclard says, that globules, analogous to those of the blood, may be seen in the colouring matter. Some anatomists assert that the rete Malpighi is not only the seat of colour, but also of the horny productions which exist in the skin of some animals, and in certain parts of that of man; this seems to be erroneous, as we shall endeavour to shew when the nails are described.

SECTION III.

OF THE DERMIS.

THE *dermis*, also called the *cutis vera* and *corium*, is a fibro-cellular membrane, which constitutes the basis and most essential part of the common integument of the body.

The external face of this structure nearly corresponds in its appearance with the outer surface of the skin before the cuticle has been removed. It presents a complicated organization, in consequence of being covered by a vascular and nervous fabric, in which the principal cutaneous functions are effected. This layer, which is frequently called, on account of its papillæ, *textus papillaris*, is described by many anatomists as a separate part of the skin; it certainly is distinguished by its great vascularity from the fibrous texture of the dermis, but for all useful purposes, it may be regarded as constituting the external layer of the latter. The papillæ of the skin were first described by Malpighi, and their existence has been since generally admitted. They consist of minute eminences, usually of an oval form, which project from the cutis, and are covered by the corpus mucosum and epidermis. In the tongue they are so large, as to be perfectly evident to the naked eye; they are also apparent in the palm of the hands, and more particularly on the ends of the fingers, and also in the sole of the foot. In the palm of the hand, and in the sole of the foot, the papillæ have a regular and peculiar arrangement; in these places they are disposed in double rows, which have usually a curvilinear direction; these rows are so very close to each other, that they may be considered as forming only one; they constitute the ridges which characterize the external surface of the corium, and which are the immediate seat of the sense of touch. In the other regions of the body these eminences are irregularly distributed, and in many parts of the skin they are so extremely small, that they have been rather admitted by analogy than from actual observation. Although in these situations the papillæ cannot be distinguished in their healthy state, they may be when they are preternaturally enlarged by disease.*

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* See Chevalier's Lectures, p. 170, and plate VII.

The papillæ, which are of sufficient size to admit of examination, appear to consist of delicate filaments of nerves and of the ramifications of the cutaneous blood-vessels and lymphatics. It is affirmed by Beclard, that they likewise receive minute and very soft processes of the dermis. Each papilla is supposed to be provided with a delicate covering of the rete Malpighianum, and also of the outer epidermis, by which means it is defended from an injurious contact with external bodies and from the varying temperature of the surrounding atmosphere.

The internal surface presents innumerable depressions, which were first noticed by Bichat. These areolæ, which differ in their size from the one-twelfth to the one-eighth part of an inch, are formed by the intercrossing and weaving of the fibres which compose the true skin. They do not entirely pierce the cutis, but end in culs de sac, which are perforated by a crowd of openings terminating on the external surface, and which may be well seen after maceration, by raising the epidermis. These openings, according to Bichat, pass obliquely, and they transmit the hairs, the blood-vessels, absorbents, and nerves.

There is considerable difference of opinion with respect to the character or even existence of the pores of the corium; but from a careful examination of this part, I am myself induced to believe that there are two kinds of orifices; one set being for the transmission of innumerable hairs, and the other for the passage of vessels. Some writers have described a third species of openings, viz. those of the sebaceous follicles; but as it is probable that these bodies are composed merely of reflected processes of the dermis, it cannot be said that their ducts actually perforate this membrane.

The cutis vera is formed of a number of small, whitish, and dense fibres, which seem to constitute a texture altogether peculiar to this organ, and which was thought by the ancients to be intermediate to the muscular and the ligamentous structures. Many anatomists suppose, that it is entirely cellular, and others that it is ligamentous; whilst Osiander contends that it is muscular. He has adopted this opinion in consequence of the observations which he made on the skin of the abdomen of women who had died in child-bed. The same idea is countenanced by Chevalier, but I believe without any real foundation in truth. Observation and experiments prove, that the dermis is formed of condensed cellular tissue, into which substance I have frequently seen it reduced after prolonged maceration. The fibres, which are interwoven together in every possible direction, are rather loosely connected on the inner surface, so that they can be there readily observed: but as they approach the outer surface, they are much more firmly combined, and can be separated only after a long continued maceration. The size and density of these fibrous threads vary according to the part in which they are examined; they are very strong and almost ligamentous on the heel; and in general it may be stated, that wherever the corium is united with aponeurotic textures, the fibres are firm and resisting. The flexibility of the skin is secured by the intermixture of a soft and gelatinous substance with the fibrous part; it is visible to the naked eye, but is rendered more apparent by continued maceration.

The vessels connected with the true skin, are very numerous, although it must be remarked, that the greater part of the sanguineous and lymphatic tubes merely pass through the cutis in order to reach its external face, so that the fibrous structure itself receives but few vessels. Where the arteries are successfully injected with size and vermilion, the outer surface has a bright red colour, whilst the substance of the true skin is nearly white, except in those places where the vessels are transmitted. This vascular network receives its supply from arteries that are lodged in the subcutaneous cellular tissue, and which permeate the corium after having partially ramified beneath it. The minute branches form delicate villi or penicilli, which are embedded in the velamina of the cuticle lined by the rete mucosum.* No vessels can be demonstrated passing to the two outer membranes of the cutaneous organ; but for the reasons I have already mentioned, I believe that they are really vascular.

The inquiries of Mr. Chevalier have induced him to consider this vascular structure, as constituting one wide and diffused perspiratory gland, conveying to the cuticle that subtle fluid which constantly exhales from the surface of the body in every degree of gradation, from the invisible vapour of perfect health to the profuse and colliquative sweat of a languishing hectic. He contends, that the perspiratory process is not merely a secretory or separative one, but is also one attended with chemical changes; and in support of this, he mentions the well-known differences which exist in the odour and other properties of the sweat of Europeans, Negroes, stances strongly point out to the surgeon the great necessity of preserving in all operations a sufficiency of skin, provided it be sound and healthy.

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* Chevalier, l. c. p. 159.

The chemical composition of the cutis vera is but imperfectly understood, notwithstanding it has received much attention from modern investigators. It contains a large quantity of water, which is readily evaporated after the epidermis has been removed. When it is dried it becomes hard, yellow, and semitransparent; if the desiccation be continued, it loses its elasticity, and even is rendered brittle; in this state it loses its great resistance, and may be torn without any great force. If it be placed in boiling water, at first it shrinks up, becomes thicker and more elastic; but if the ebullition be continued, it is reduced into a softer substance, and ultimately it is dissolved, and the solution contains a large quantity of gelatine. The observations of Seguin and others seem to prove that there are two distinct substances in the corium; one of which consists of dense fibres forming its basis, and the other of a semifluid matter, interposed and contained between them.* The cutis, by combining with tannin and the extract of oak bark, is converted into that useful article, leather. Chevalier states that in this process, the soft substance above mentioned, is in part, or wholly separated in the macerating pits of the tanner, before it is subjected to the full influence of the tannin.

The colour of the cutis is greyish white, intermixed in some places with a reddish tinge, which seems to be produced by the injection of its blood-vessels. The thickness of this structure is subject to vary from two lines to the one-fourth of a line, according to its situation, and also according to the sex, age, and constitution of the individual. It is remarkably thick on the heel, in the palm of the hand, and on the scalp. On the back it is usually of great thickness; in one of the measurements which I lately made in a male, the dimension in this part was the one-fifth of an inch. It is thin on the face generally, especially on the lips and eyelids; also on the auricle of the ear, on the penis and scrotum, and in the female on the labia pudendi. In many parts of the body the dermis is so thin as to be semitransparent, allowing the colour of the parts beneath to be seen; thus the purple hue of the blood is often distinguished in the superficial veins, especially in the delicate skin of the female.

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* See p. 179.

It is very strong and resisting, and in this respect it exceeds most other parts of the body. This property, which is owing to its great density, remains after death: and by tanning it is even increased, the strongest ties that are employed by mechanics being formed of the leather which is produced by that process. The cutis is highly elastic, so that after it has been extended, and this may be done to a considerable degree, it readily contracts on itself to its original state.

The uses of the cutis vera are complicated and important. In the first place, by its dense and fibrous structure, it supports the more delicate textures which are placed on it; whilst by its vascular and nervous fabric, it accomplishes most of the numerous operations which are carried on in the external cutaneous system. It furnishes the secreting and absorbing vessels, by whose agency the essential functions of extrinsic secretion and absorption are effected. Lastly, it is the seat of touch in all its varying degrees of perfection.

SECTION IV.

OF THE SEBACEOUS FOLLICLES.

THESE minute bodies appear to be formed of culs de sac, which are principally placed on the external surface of the cutis, and are lined by processes of the cuticle. Many anatomists are of an opposite opinion, and contend that they are distinct glands. This opinion is supported by Mr. Chevalier, who states that there are two orders of sebaceous glands; one set being partially or entirely imbedded in the corium, and the other, which is less known, lying between the rete mucosum and the cuticle. The latter may be seen adhering to the internal surface of the cuticle, after a maceration of several weeks, which will cause the rete mucosum to be so much decomposed that it may be washed or rubbed off.

The mouths, or ducts of these little follicles, which open obliquely on the cuticle, are very apparent on the nose, in consequence of their greater size; they are also seen on the edges of the eyelids, on the cheeks, on the nipple, in the axilla, around the anus, &c.

The arrangement of the sebaceous glands varies according to their situation. On the palmar surface of the thumb and fingers, they are disposed in rows, which correspond with the linear projections seen on the exterior; in other parts of the body there is no regular order observed in their disposition. We learn from the statement of Mr. Chevalier, that the number of these bodies is almost incredible; in one of his preparations deposited in the museum of the College of Surgeons, no less than one hundred and thirty of them may be counted with the naked eye in the surface of $\frac{1}{24}$ part of a square inch.*

The follicles of the skin are provided for its defence against the influence of the air and moisture. They secrete an unctuous matter of a whitish colour, which constantly bedews the external surface, so as to preserve the softness and smoothness which are required for the proper exercise of the cutaneous functions. This secretion repels aqueous fluids, as we readily observe when the hand or other part of the body is placed in water; it also prevents, in a great degree, the effects of friction; this is evidenced in the armpit, which is so frequently rubbed in the movements of the upper extremity.

The sebaceous matter frequently accumulates in the ducts, from whence it may be squeezed out in the form of small worms, of a yellowish colour, and dark on the ends, so as to look like heads. It is not soluble in water, although it may be mixed with it, so as to form a kind of emulsion. It is not readily inflammable, but it burns and leaves in its residue a quantity of charcoal. It appears to consist principally of ceraceous and oleaginous particles. It is necessary to add, that the secretion of the sebaceous glands is totally distinct from the matter of perspiration. This is illustrated by the simple experiment of placing the end of the thumb or finger, moderately heated, on a polished mirror, when it is always found that the stain of the perspiration is left on the glass everywhere, except at the orifices of these follicles, proving that they cannot be the source of the vapour which is exhaled.

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* See Lectures, Plates 3, 4, and 5.

SECTION V.

OF THE APPENDAGES OF THE SKIN.

In the preceding pages the structure of the skin has been examined; but in order to render the description of that organ complete, it is requisite to consider its appendages, which consist, in the human species, of the hairs and the nails. In animals, many other productions are observed, such as horns, feathers, scales, &c.

OF THE HAIRS.

The hairs, called, according to their situation and size, *pili*, *crines*, *barba*, *capilli*, *capilluli*, &c. are horny filaments placed on the exterior of the body, and which are intimately connected with all the layers of the skin, and not merely with the epidermis, as some anatomists have erroneously supposed. In man the large hairs are confined to certain parts, whilst in quadrupeds they extend over the entire surface. It must be noticed, however, that all parts of the body, excepting the palm of the hand and sole of the foot, are covered by minute hairs, constituting the pubescence or down; a fact which justifies the observation of Haller, that man is naturally a hairy animal, and that the face of the most delicate woman is entirely covered with hair. The head is the principal seat of the hairs. On the scalp they are very numerous, long, and strong; the length of these hairs is sometimes so great, that they reach towards the lower part of the body. The eyebrows and eyelashes, which are distinguished by their curved form and direction, are implanted around the eyes, being provided for the defence of those organs against the entrance of foreign substances. The orifices of the nostrils, and, in a less degree, those of the ear, are defended by some hairs which are lodged in the beginning of their respective passages. The cheeks, the lips, and chin, are occupied, in the male after puberty, by the beard, the extent and strength of which are liable to great variation. The hairs of the trunk and limbs are not so numerous nor so constant as those of the head, with the exception of those surrounding the organs of generation, which are always developed at the period of puberty. The armpits are provided with hairs, which are seldom deficient; the anterior part of the body possesses more hair than the posterior part, and the lower extremities are better furnished with it than the superior. The hair is confined on the hands and feet to their dorsal surfaces, the absence of it in the opposite direction being subservient to the perfection of the sense of touch.

The development of the hair is greatly influenced by the organs of generation; thus the beard in the male does not make its appearance till the time of puberty; and if the testes are removed, as in eunuchs, or are not properly formed, the beard is usually weak; it is also seen that in the boy the limbs are merely covered with down. In the female, the hair of the head does not attain its full growth till the same epoch; and in both sexes the genitals are till then defective in their covering.

The colour of the hair has a close relation with that of the skin, and, consequently, exhibits like it, innumerable shades; it is of a brown or red colour in fair persons, and black in the dark races of mankind. In the Albino it is of a milky whiteness; and in those Negroes who have a spotted skin, the hair is white or black, according to the colour of the patches it covers. It is probable that the colouring matter is derived from the vessels which pass into the hair itself, for it cannot be furnished by the root, which is always white, whatever may be the colour of the hair; nor can it proceed from the rete mucosum, even supposing that this covers the hair, which is not satisfactorily ascertained, because the colour of the rete is not always the same as that of the hair, which must have been the case if the shade of the latter was derived from the former.

Each hair consists of a root placed under the skin, and of a stalk which projects beyond the external surface. The root is contained in a bulb, which is situated in the subcutaneous cellular tissue or in the cutis vera; it is of a conical shape, the large end being connected with the skin and the small end with the cellular texture. The bulb, or as it is also called the follicle of the hair, has been minutely described, especially by Chirac and Gordon. It is formed externally of a capsular membrane, which is whitish, and appears to be derived from the corium. Within it there is another and more delicate membrane, containing a conical papilla, which is received into the root of the hair. Sanguineous vessels, and, according to some anatomists, even nerves may be traced to this papilla. The root of the hair is always whitish and semitransparent, whatever may be the colour of the stalk. It is soft, and the lower part, which is almost fluid, is rather hollowed to receive the papilla, on which it rests. The stalk, or the part that projects beyond the skin, is conical; it gradually tapers from the root to the point, and is often split into two, towards the extremity.

Immediately after leaving the bulb, the hair is received into a canal of the cutis, which is always more or less oblique. The connexion between the hair and the epidermis is not so satisfactorily ascertained. Many anatomists think that the cuticle, and also the rete mucosum, furnish a sheath to the hair; but others deny this, and contend that the epidermis is perforated. The former opinion is probably correct, because there is a great resemblance in the characters of hair and cuticle; and when the latter is separated by putrefaction from the cutis, most of the hairs, owing to the intimate union with it, are also detached.

The hair, when it is seen through the microscope, appears to be semitransparent, and to have a central dark-coloured canal, which is filled by a peculiar substance. It is said, that there is an external horny sheath; and that a number of filaments, varying from five to ten, are contained within it; but I have not myself been able to detect such appearances.

It is generally thought that the hair, which grows from the organized bulb, is in itself non-vascular; but an opposite opinion has been supported by some writers, with whom I am inclined to agree, although, it must be admitted, that no vessels have been satisfactorily demonstrated. The deposition of the colouring matter, and the sudden changes which have been known to occur in the hair from the effects of mental emotion;* and even from excessive venery, seem to prove the existence of nutritious arteries. It is almost needless to add, that if any vessels pass to the hairs, they are extremely small, and certainly would not bleed, as some persons have imagined they do, when divided in the disease called *plica polonica.*

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* Many instances occurred during the horrors of the French Revolution, of the hair turning grey in the course of a few days, and this change has even taken place in a single night.

The hairs, which are apparently destitute of nerves, are quite insensible. A curious case of phrenitis, however, is quoted by Dr. Elliotson, in which the hair was so sensible, that the slightest touch gave severe pain; and when the surgeon clipped a hair unseen by the patient, this was instantly felt, and occasioned a paroxysm of rage.

The hairs are first seen in the fœtus towards the middle of pregnancy; they consist, at that period, of globules which are placed under the external surface of the body. They afterwards are elongated, and then they appear on the skin in the form of a very fine and colourless down, the larger part of which is detached at the eighth month of gestation, and the remainder soon after birth. The hairs of the head, the eyebrows, and the cilia, begin to appear about the fifth month; but they are very delicate, and imperfectly coloured at the time of birth.

We learn from Vauquelin, to whom we are indebted for an analysis of hair, that it consists principally of an animal matter united to a portion of oil. He states that the former is a species of mucus; but Mr. Hatchett has ascertained that it is chiefly albumen united to a small quantity of jelly, the proportion of which varies. This distinguished chemist concludes from many experiments, that the hair which loses its curl in moist weather, and which is the softest and most flexible, is that which most readily yields gelatine, on boiling; while that which is very strong and elastic, affords it with the greatest difficulty, and in the smallest proportion. The colouring matter appears to consist of an oily substance united to a small portion of iron and sulphur; this oil is black when the hair employed is dark, and yellowish red from red hair. Vauquelin observed, that hair yielded, by incineration, iron and manganese imparting a brownish yellow colour to the ashes; phosphate, sulphate, and carbonate of lime; a little of the muriate of soda, and a considerable portion of silica. When hair is thus burnt, it exhales a smell like that of the epidermis, and in other respects it has a close resemblance to that substance.

The use of the hairs in the human subject, is not so apparent as it is in the inferior animals, in which they obviously protect the body from external cold. They afford a defence to the skin, and on the head they serve as an ornament. It has also been supposed that, as they pass from the dermis to the surface of the body, perforating, or rather elongating the rete mucosum and the epidermis, they must serve to connect together all the layers of the integuments like so many fine pins or fastenings.

OF THE NAILS.

The nails, *ungues*, like the hairs, are appendages of the skin, and not merely of the epidermis, although they are so intimately connected with the latter, that many authors have described them as being altogether derived from it.

These bodies are hard transparent plates, which cover the dorsal extremities of the third phalanges of the fingers and toes. They are oblong in shape, and present a considerable convexity from side to side. The nails of the human species differ from those of most animals, by their comparative width and by their tenuity. These peculiarities of form and texture relate to the connexion which these bodies have to the exercise of touch.

Each nail possesses three parts, viz. the posterior part or root; the middle part or body; and the anterior part or free extremity. The root is the softest and thinnest portion; it is concealed under the skin, and forms about one-sixth or one-fifth of the whole nail. The body or principal part of the nail has two surfaces; the external one is free, and presents several longitudinal grooves, which are more or less distinct; the opposite face intimately adheres to the skin. The greater portion of the body has a reddish colour, which, however, does not belong to the nail, but to the vascular cutis placed beneath it, and which is seen through its transparent covering. Near the root the nail is opake and white; the opacity, which has the form of a half-moon, (*la lunule*) varies in different individuals, but it is always proportioned to the size of the nail. The anterior extremity, which is the thickest part, passes rather beyond the level of the skin, and is consequently unattached on both surfaces. This end requires to be cut from time to time, in proportion as it grows beyond the finger. If this is not done, the nail increases in length and thickness, and curves towards the palm of the hand, so as to cover the finger, and thus to interfere with touch. In some countries it is a custom among the higher classes of people, to allow the unrestrained growth of their nails, in order to shew, in an indisputable manner, that they are removed from the necessity of manual labour.

The connexions of the nail are rather complicated, which may explain the contradictions that are met with in writers on this subject. The nail is intimately united by its root and internal face with the dermis. The former, which is thin and soft, is received into a fold of the cutis; and the body, which is internally soft, and furnished with longitudinal grooves, receives the vascular ridges of the true skin. The epidermis, which is so firmly attached to the nails, that both are separated from the cutis by the same causes, as it approaches the margin of the nail, turns towards the root, and thus forms a kind of grooved rim, which, being insensible, may be cut away without causing any pain. When the epidermis has reached the root, it is reflected over the external face, so as to cover it with a very thin and superficial layer. At the free extremity of the nail, the cuticle of the end of the finger is reflected on its deep face, and is then continued, on the external surface, with the above-mentioned layer.

The nails are semitransparent, elastic, and resisting; they tear across, notwithstanding their fibrous appearance, in the opposite direction. They consist of a horny substance, which has a considerable resemblance to the epidermis. No vessels can be demonstrated, although the constant growth which the nails exhibit, and also their regeneration after they have been destroyed, prove that they receive a supply of blood. The force of formation is so very considerable, that, according to Blumenbach, they are perfectly renewed about every six months. They do not possess any nerves, and, consequently, they are totally insensible.

These bodies begin to appear towards the middle of the fœtal existence; but they are imperfectly formed even at the time of birth. They are chiefly composed of albumen, with different proportions of jelly and mucus; they also appear to contain a little of the phosphate of lime.

The uses of the nails are confined in the human species to increasing the perfection of the organ of touch. They support the skin on the extremities of the fingers, and preserve it in the state of tension which fits it to receive the slightest impressions. When the nails are lost, the skin shrinks, and is, in a great degree, deprived of its delicate sensibility.

SECTION VI.

FUNCTIONS OF THE SKIN.

IN many of the inferior animals the thick and even horny integument serves as a kind of armour against mechanical violence. But in the human species the defensive power of the skin, is principally limited to protecting the surface of the body from the injurious influence of chemical agents. This important object is accomplished by the secretion of the small arteries, and of the sebaceous follicles.

The capillary vessels of the skin secrete a watery fluid, which is constantly passing off from the external surface, either in the form of vapour, when it is called the insensible perspiration, or in that of liquid, when it is distinguished as the sweat. Many circumstances affect the cutaneous transpiration, especially the condition of the atmosphere and the state of the individual; it is, therefore, difficult to form an accurate estimate of its quantity.* The experiments which were performed with so much care and skill by Lavoisier and Seguin, to determine this point, are generally considered to be satisfactory. According to their authority, the average discharge from the skin amounts to thirty ounces, and that from the lungs to fifteen ounces in twenty-four hours. It is worthy of remark that Haller had previously estimated the insensible perspiration at twenty-eight ounces in twenty-four hours, and that, subsequently, Mr. Abernethy has found that about two pounds and a half of aqueous fluid are perspired daily from a person of ordinary stature.

The transpired fluid is usually imperceptible, in consequence of being carried off by evaporation as quickly as it is separated from the blood; but when from an increased activity of the capillary arteries, or from a diminution of the solvent powers of the atmosphere, or from both these causes united, the secreted matter is not immediately evaporated, it accumulates in small drops on the surface of the skin, and thus forms the sensible perspiration, or sweat.

The matter which is excreted appears to be essentially the same in each instance, the only difference relating to its quantity. It consists of water, which holds in solution hydrochlorate of potash and soda, lactic or acetic acid, and a small proportion of animal matter, probably mucus or albumen. The cutaneous transpiration, if we may judge by its odour, has not always the same qualities. It has a strong smell in the armpits and feet of many persons, and it is especially nauseous and disagreeable in Negroes. The cutaneous transpiration ought to be regarded as a necessary and important excretion, for whenever it is diminished or suspended, serious disturbance is produced in the economy.

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* The excellent work of Dr. Edwards contains a great deal of valuable information on this subject. See "De l'Influence des Agens Physiques sur la Vie," p. 312, *et seq.*

The perspiration has also a great influence in reducing the heat of the body. This is proved by the observations of Dr. De la Roche and others, who found that animals are capable of resisting a high temperature in proportion to the cutaneous evaporation.*

The researches of Cruikshank, and the later ones of Mr. Abernethy, prove that the air in which the hand or foot was confined for a certain time, contained a quantity of carbonic acid; and Dr. Edwards has shewn, that in frogs and other inferior animals, the respiratory process of the skin is nearly equal to that of the lungs. It is therefore probable that the skin secretes carbonic acid, but that the quantity is small in man, in whom the pulmonary organs are so greatly developed.

The surface of the body is bedewed with an oily matter, which is secreted by the sebaceous follicles. Cruikshank obtained this substance from the surface of a flannel waistcoat which he had worn during a month in the hottest time of summer. It consisted of a black and greasy matter, which was inflammable, and left, after being burnt, a carbonaceous residue.

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* The experiments of Sir C. Blagden, Dr. Solander, and others, shewing the power which the animal body possesses of resisting for a time a high temperature, are well known. I have lately had an opportunity of witnessing a similar experiment, which was performed by Mons. Chabert. This person went into an oven, of which the temperature was 390°; he remained there about seven minutes, which time was sufficient to cook the beef-steaks that he took with him into the oven. He came out in a profuse perspiration, and his pulse, which I ascertained were 95 at the beginning of the experiment, had risen to 160. With the exception of these effects, he did not appear, either whilst in the oven or afterwards, to be in the least inconvenienced by this curious performance. I have heard from others, that M. Chabert has frequently gone into the oven at a much higher temperature than that above mentioned.

The preceding observations demonstrate the complicated nature of the cutaneous excretion, and prove that it consists of three distinct substances: 1. The aqueous fluid of perspiration. 2. Gaseous matter. 3. The unctuous secretion of the sebaceous follicles.

The absorbing power of the skin, unless aided by friction,. or by the abrasion of the epidermis, has been generally doubted by modern physiologists. A contrary opinion was entertained by Sanctorius, and by others who repeated his experiments. The investigations of Dr. Edwards,* which have done so much to determine many of the disputed questions of physiology, shew that absorption takes place, to a very considerable extent, without friction or abrasion. This was proved by placing frogs, toads, and lizards in water, when it was found that their weight was increased by cutaneous absorption. But in making this statement, it is not intended to deny that friction, and still more the removal of the cuticle, greatly increase the absorbing power of the surface of the body.

The observations of Mr. Abernethy would lead us to conclude, that the skin also absorbs certain gaseous substances, in addition to aqueous matter. Thus he found that the hand and wrist imbibed eight ounces of oxygen gas in eight hours, and one ounce of azote in the same period.

The last function of the skin which remains to be considered, is that which depends on the sensibility with which it is endowed. This property is greatly developed in the human species, conferring a delicacy of sensation which is wanting in animals. Every portion of the external surface is capable of receiving the impressions of surrounding bodies; but many of their qualities can only be ascertained in an accurate manner, by a small part of the skin. These two modifications of cutaneous sensibility have been distinguished by the names of tact and touch. Tact is exercised generally over the skin; whilst the sense of touch is confined to the hands, and in a less degree to the feet. The latter being more perfect than the other senses, and less liable to error, has been called the geometrical sense. A very little reflection, however, will convince us, that most physiologists have considerably overrated the perfection of this function.

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* De l'Influence, &c. p. 345, *et seq.*

PART THIRD.

OF THE MUCOUS MEMBRANES.

The mucous membranes form the internal portion of the tegumentary system. The name was applied in the first instance, to the membrane of the nostrils, in consequence of the mucus which it secretes. In the present day, the term has been extended to the membranous lining of all those cavities which have external communications; so that, considered in this manner, it is much more extensive than the skin. The similarity of the secretion of the different parts of this system, and the general existence of follicles throughout its various divisions, caused anatomists to suspect that all these membranes were identical in their structure, and subsequent investigations have satisfactorily confirmed these surmises. The honour of giving the first distinct history of these textures, is due to Bichat;* although Pinel had previously remarked their similarity in a pathological point of view.

Section I.

DISPOSITION OF THE MUCOUS MEMBRANES.

The cavities and organs which are lined by these membranes, are placed in such distinct regions of the body, and they are otherwise so distinct from each other in structure and function, that it is difficult to conceive that they are all connected together by a continuous surface. Anatomical examination, however, proves this continuity in an incontrovertible manner; and in order to render it apparent, I shall follow the example of Bichat, who demonstrated that all the membranes of this system might be reduced to two great divisions, viz. the gastro-pulmonary and the genito-urinary.

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* See Traité des Membranes.

The first division enters the interior of the body through the mouth, the nostrils, and the lachrymal passages. After lining the oral and nasal cavities, it is reflected from the former along the excretory tubes of the parotid, submaxillary, and sublingual glands; whilst from the latter it is continued within the different sinuses of the head. That portion which belongs to the lachrymal passages, after having covered the surface of the eye and eyelids, is reflected at the external part of the globe, along the ducts of the lachrymal gland; and at the internal canthus it extends within the lachrymal puncta, the lachrymal sack, and the nasal duct, and in this manner becomes continuous with the membrane of the nostrils. The mucous surface of the mouth and nose is then continued backwards into the pharynx, from each side of which it passes along the eustachian tube, and thus reaches the cavity of the tympanum and the mastoid cells. At the lower part of the pharyngeal bag, the membrane sends off two great processes; the anterior one being reflected through the larynx, the trachea, and the bronchi, penetrates into their minute terminations, which constitute the air-cells; the posterior portion extends along the œsophagus, lines the stomach, and then enters the duodenum. In this intestine the mucous membrane furnishes two processes; one of which is prolonged into the ductus choledochus, into the ductus hepaticus as far as its origin, and into the ductus cysticus and gall bladder; the second portion lines the ductus pancreaticus and its numerous branches. The mucous surface is continued from the duodenum along the remaining part of the small intestine; it then enters the large intestine, and ultimately ending at the anus, it again becomes continuous with the external integument.

The second great division of the mucous system, the genito-urinary, is much less extensive than the first, although it penetrates very deeply into the interior of the body. In man it enters by the orifice of the urethra; it lines that canal, and at its prostatic portion it sends off some processes, which pass into the ducts of the prostate gland; and others which are reflected on the one part, along the excretory tubes of the vesiculæ seminales, so as to afford a lining to those bodies, and on the other, along the vasa deferentia and their complicated ramifications within the testes. The mucous membrane is afterwards continued from the urethra into the urinary bladder; it lines that viscus, the ureters, the pelves of the kidneys, the infundibula, the papillæ, and in all probability the uriniferous tubes.

The membrane in the female enters the vulva; one portion of it is reflected through the urethra, and then within the urinary passages, as in the male. The other part lines the vagina, the uterus, and the fallopian tubes, and becomes ultimately continuous at their fimbriated extremities with the serous membrane of the broad ligaments.

In the preceding enumeration I have not included a small insulated process of the membrane, which lines the lactiferous ducts of the female mammæ; it is, in consequence of its small extent, comparatively unimportant.

The adherent surface of the mucous membranes is united by cellular tissue to the various parts by which they are surrounded. The principal division of this system is joined to the plane of fleshy fibres that belongs to the alimentary canal, and which constitutes a kind of internal cutaneous muscle. In other places, as in the larynx and air-tubes, the membrane is connected with a cartilaginous structure; and elsewhere, to a ligamentous texture, as to the periosteum of the nares, of the sinuses, palate, &c.

The firmness of the above connexions is variable; it is inconsiderable in the nasal fossæ, the intestinal canal, and the urinary bladder; whilst the union is very intimate on the tongue, the palate, &c.

The free surface possesses a very complicated structure, which is subservient to the important functions that are exercised in the mucous membranes. It has an unequal appearance, in consequence of numerous valves, folds, and wrinkles, projecting on most parts of its extent. The valves are formed not only of duplicatures of the mucous membrane, but also of the subjacent muscular fibres; there are examples of them in the valve of the pylorus, in that of the ileum, and in the velum palati. The folds contain only the submucous tissue within them; they are, however, as constant as the valves, and are never obliterated by distention; such are the valvulæ conniventes of the intestines, and the spiral projections within the cystic duct. The wrinkles, on the contrary, depend on accidental circumstances for their production: they are principally seen within the hollow viscera when they are empty, as in the stomach, gall-bladder, and urinary bladder; also in the œsophagus, vagina, &c. These folds, which depend on the relaxation of the mucous surface after it has been distended, are evidently provided for the purpose of permitting the great increase to which the above organs are so frequently liable.

In addition to the valves and folds, this surface presents a great number of papillæ, villi, and follicles, the description of which bodies is deferred till the following section.

SECTION II.

ORGANIZATION OF THE MUCOUS MEMBRANES.

THE basis of these membranes consists of a layer of condensed cellular substance, which was denominated by Bichat, from its resemblance to the coriaceous part of the skin, the mucous corium; it has also been usually distinguished in the alimentary canal, by the name of tunica nervea. This lamina supports a vascular and delicate structure, which forms the external surface of the mucous system.

It has been shewn, in a former part of this chapter, that the epidermis can be demonstrated in several parts of this system, and that in certain directions, as along the œsophagus, it penetrates rather deeply into the body. But in most of the internal organs, it appears that the place of the epidermis is supplied by the mucous secretion, which affords an efficient protection against the foreign substances that are constantly passing through them. Haller, and others, entertained an opposite opinion, and urged in support of it, the occasional discharge from the stomach, bladder, &c., of membranes having the exact form of those organs, and which were thought to be their cuticular lining. It is certain, however, that these membranes must have been portions of fibrin, which were produced by inflammation.

There is no structure that can be assimilated with the corpus mucosum of the external integument, and consequently in the Negro the mucous surfaces have the same appearance as in the European. One exception, perhaps, ought to be made, viz. in the tongue, where the papillæ are separated from the epidermis by a layer of coagulable liquid, which, in fact, being observed by Malpighi, led to the discovery of the substance which has since been distinguished by the name of that celebrated anatomist.

The mucous corium forms the basis and support of the mucous system. Its thickness varies in the different regions which it occupies. It is extremely thin in the sinuses of the head, and in the excretory ducts; it becomes successively thicker in the urinary bladder, in the large intestines, the gall-bladder, the small intestines, the stomach, the nasal fossæ, the palate, and the gums. The density of this membrane also exhibits variations, which are very apparent by comparing a part that is placed towards any of the external openings, with another portion taken from the interior of the body. The cellular tissue which forms the corium of the mucous membrane has not, like the tissue of the cutaneous dermis, a regularly areolated disposition; it is generally fibrous, but in many parts, and particularly in the pituitary membrane, it has a spongy or even fungous structure.

The mucous corium is covered by a vascular structure, which is analogous to the papillary texture placed on the outer surface of the cutis vera; it consists of the papillæ, villi, and follicles.

OF THE PAPILLÆ AND VILLI.

These bodies, which consist of an infinite number of projections, have received their appellation from their supposed resemblance to small nipples and to the pile of velvet.

The papillæ are sufficiently large to be seen by the naked eye, particularly on the tongue, where they are very much developed. On the dorsum of this organ, there are four classes of papillæ, which are distinguished according to their various forms into the filiform, the conical, the fungiform, and the lenticular or truncated. Their size is also subject to variation; and hence they are termed the papillæ majores, mediæ, &c.

The villi or villosities are much smaller than the preceding eminences, and indeed the aid of a lens is usually required to see them distinctly. In the small intestines they are larger than those of the stomach; their length is usually about the 1-4th of a line, but in the upper part of the small intestine they are occasionally thicker and shorter than they are at the lower part; their number is extraordinary, about four thousand having been counted on a square inch of surface.* In the large intestine and in the bladder they are less distinct, and in the sinuses of the head they are scarcely perceptible. The villosities, according to Beclard, are not conical, cylindrical, nor tube-like; they have rather the form of leaves and laminæ, which are of different sizes, and variously disposed in the stomach, jejunum, colon, &c. The papillæ and villi consist of a delicate cellular tissue, in the substance and on the surface of which are distributed sanguineous and lymphatic vessels; and the former of these eminences receive nervous filaments.

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* Meckel, Manuel d'Anatomie, t. iii. p. 396.

The presence of arteries is proved by the effects of injection, and they become still more apparent when viewed by the microscope. The veins, which are numerous, have an erectile disposition. The absorbents are more difficult to demonstrate, on account of their great tenuity; but there is no doubt of their existence. Although these vessels can be injected, it is extremely difficult to ascertain how they begin. They have been examined with the greatest care in the villi of the small intestine, by Dr. W. Hunter and Mr. Cruikshank. The latter states, that the orifices of the lacteal vessels were very distinct, and that from 15 to 20 of them could be seen on a single villus of the jejunum.* On the contrary, Rudolphi and others deny that the chyliferous vessels have open mouths; they suppose, that the villi consist of a spongy and gelatinous substance, which is the seat of absorption. The opinion of Cruikshank appears to be nearest the truth; but as his deductions were drawn from microscopical observations, and as the correctness of them has been called in question by some high authorities, it is necessary to regard this question as being still involved in uncertainty.

The papillæ of the tongue, of the nostrils, and of the glans penis, receive nerves; but it is impossible, even with the microscope, to detect any filaments in the villi of other organs; although the arguments of Bichat concerning the sensibility of these bodies, certainly lead to the conclusion that they possess nerves.*

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* Anat. of the Absorbing Vessels, p. 59.

OF THE MUCOUS GLANDS OR FOLLICLES.

The membranes of this system have their free surface lubricated by a mucous fluid, which is derived from a great number of minute follicles or glands, *glandulæ vel cryptæ mucosæ.*

It is generally admitted, at the present day, that each of these bodies consists of a small cul de sac formed of the membrane reversed on itself, and placed in the submucous tissue, by which it is strengthened, and where it necessarily makes a projection. They exist in all parts of the mucous membranes, but their shape, number, and size, are subject to much variation. They are usually rounded or oval, although frequently they are infundibular or lenticular. In the palate, bronchi, œsophagus, and especially in the intestinal canal, they are very numerous. The smallest of them, which are met with in great numbers, *cryptæ minimæ*, are equally dispersed on most of the mucous membranes. In the duodenum there are some of larger size, each of them having a diameter of about a line; they are disposed in an insulated order, and are hence termed *glandulæ solitariæ;* and also glands of Brunner. In the ileum being placed in clusters, they are called *glandulæ aggregatæ*, or glands of Peyer; the follicles which form the caruncula lachrymalis, appear to belong to this class. There are some examples of compound mucous follicles, which have a great resemblance to proper glands; such are the tonsils, the glands of Cowper, and even according to some anatomists, the prostate gland. Lastly, many of the follicles, which are of large size, have wide orifices; they are known by the name of *lacunæ*, as the lacunæ of the urethra, of the rectum, &c.

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* Anat. Gen. t. ii. p. 496, *et seq.*

The follicles receive a great number of vessels. It is impossible to trace any nerves, although analogy renders it probable that they exist.

SECTION III.

PROPERTIES AND FUNCTIONS.

THE colour of the mucous membranes is much more uniform than that of the skin; it varies from a pale yellow to a deep red, and very often it has a mottled appearance. These varieties seem to depend principally, though not entirely, on the quantity of blood that circulates in the different parts of this system. The other physical powers of these membranes, viz. their density, extensibility, and elasticity, have been considered in the first part of this chapter.*

It was also stated, in the same place, that the sensibility of the mucous surfaces, with the exceptions there mentioned, is of that kind which is not perceived by the mind. It is probable, however, that the feelings of hunger, thirst, repletion, &c., depend on the sensibility of the gastric membrane; and likewise that the uneasy sensations which are caused by holding the breath, and by retaining the urine and fæces, are respectively dependent on the sensibility possessed by the lining coat of the lungs, the bladder, and rectum.

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* See p. 180.

The investigation of the diversified functions that are accomplished by the mucous membranes, falls within the province of the physiologist. I shall, therefore, merely allude to the operations which are carried on in common by all the divisions of this system.

The most essential of these processes is absorption; a function which exhibits many variations in the degree of its activity and importance, and also as to the substances which are exposed to its action. Thus, in the intestines, the villi take up the chyle, in the lungs they absorb certain gases, and in other organs they imbibe various substances according to the office of the part.

Secretion is another function that is shared in common by the mucous membranes; and, like the same process in the skin, it is of a twofold character, perspiratory and follicular. The fluids separated by the former process, differ according to the organ in which they are secreted.

The nature of the follicular secretions is also various in different parts; thus the substance secreted by the tonsils is very offensive to the smell, particularly when it is at all vitiated; and, again, the odour of the secretion from the genital mucous membrane, is peculiar, especially in the females of many animals. The common product of the mucous follicles is, however, a viscid, whitish, and transparent fluid, called *mucus*. It is soluble in water and in dilute sulphuric acid; it is not coagulated by heat, nor precipitated by corrosive sublimate. The nasal and bronchial mucus analysed by Berzelius, consists of:

Water	933·9
Mucous matter	53·3
Hydrochlorate of Potash and Soda	5·6
Lactate (Acetate) of Soda and Animal matter	3·0
Soda	0·9
Phosphate of Soda, Albumen, and Animal matter	3·3
	1000·0

Mucus, being one of the immediate principles of animal organization, is found in many of the fluid and solid materials of the body.

CHAPTER FOURTH.

OF THE VASCULAR SYSTEM.

The vascular system, *systema vasorum*, is composed of a great number of canals, by which the nutritive fluid is conveyed into all parts of the body, and subsequently returned to the place whence it set out. This system is also distinguished by the name of *circulatory*, because the blood, as it moves within it, describes a kind of circle.

In man, and in the more perfect animals, the organs of the circulation consist of three distinct orders. 1. The arteries. 2. The veins. 3. The lymphatics. The two former classes of vessels communicate with a muscular and hollow organ, called the heart, from which the arteries receive their supply of blood in order to carry it into the various tissues, and to which the veins bring back the nutritious fluid after it has thus been distributed. The third set of vessels, which constitutes an appendage to the veins, is not filled with blood, but with chyle and lymph. The lymphatic vessels are, in the present day, generally included in the vascular system; but some writers, on account of the differences which exist in the structure, functions, and diseased actions of the lymphatics, and of the blood-vessels, object to such an arrangement as being more likely to mislead than instruct.* There are, however, several reasons which may be urged in favour of the plan I have adopted in this chapter. In the first place, there is a considerable similarity in the texture of the lymphatics and of the veins; secondly, the disposition and course of the two sets of vessels bear a striking resemblance to each other; thirdly, the lymphatic vessels form large communications with the trunks of the veins, and even with their branches; they also appear to communicate with the arteries, as they have been injected from them; fourthly, and more especially, the functions of the absorbents are closely connected with, and essential to, those of the arteries and veins. It is upon these grounds collectively, that the association of the lymphatics with the blood-vessels is supported.

In the inferior tribes there are no distinct organs of circulation, the nutritious fluid being absorbed by the parietes of the digestive apparatus, and immediately conveyed into the areolar substance of the body.† In insects there is a dorsal vessel, which is closed at the extremities; it pulsates, but no branches can be distinguished proceeding from it, although Professor Carus has lately discovered in these animals a circulation through a granular substance. The first distinct traces of blood-vessels are met with in some intestinal worms; but with respect to the lymphatic and chyliferous vessels, they are, as far as we know, possessed only by the vertebrata.

The existence of a heart is by no means so constant as that of circulating vessels, the first rudiment of this organ being observed in the pulsating tube of insects.

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* Magendie, Comp. of Phy. Note by Dr. Milligan, p. 528.

† Cuvier, Leçons d'Anat. Comp. t. iv. p. 167.

The mechanical structure of the heart is extremely various in the different classes of animals. In its most simple form, it consists of a fleshy bag, called *a ventricle*, which forces the blood into an artery; there is frequently added to this cavity another, termed *an auricle*, which may be regarded as constituting a sinus at the termination of the veins. The single heart presents three varieties:—1. The heart is said to be *aortic* or *systemic*, when the ventricle sends the blood to all parts of the body. 2. It is *pulmonic*, when the ventricle propels the circulating fluid to the pulmonary organs. 3. It is both aortic and pulmonic, when the ventricle forces the blood at the same time towards the body and the pulmonary organs. The heart is simple, without an auricle, and pulmonic, in all the articulated animals which are provided with it. In fishes the heart is also single and pulmonic, but it possesses an auricle; it propels the blood to the gills, whence the nutritive fluid is carried to the body by a large artery, which serves the office of a systemic ventricle. The mollusca, with some exceptions, have a simple heart, which is aortic, but without an auricle. The cuttle fish has a most curious structure, the heart consisting of three separate and detached ventricles, two of which are pulmonic and one aortic. In all the amphibia the ventricle is single, although it is often divided into partitions, as in the turtle, and thus appears to be double or triple; the heart in these animals is both systemic and pulmonic, furnishing at the same time the blood of the aorta and of the arteries passing to the lungs; there are generally two auricles, but in some instances only one.

Lastly, the heart in birds and mammalia is perfectly double, each side possessing a distinct auricle and ventricle, which have no communication with the opposite cavities. The right heart is destined to the circulation of the lungs, and is therefore pulmonic; while the left, performing the circulation of the body, is aortic.

The discovery of the circulation of the blood was made by our illustrious countryman, Harvey, about the year 1619.* It appears that he was led to it by reflecting on the arrangement of the valves of the heart and veins, which were described by Fabricius, whose lectures Harvey had attended. Some parts of the circulation were imperfectly known to Servetus, Colombo, and Cesalpini, in the sixteenth century; but the ideas of these physiologists were confined to a few facts, and were obscured by a number of erroneous opinions.

The circulation of the blood has been divided since the time of Harvey, into two parts, or, in other words, it is said that there are two circulations, the greater and the lesser. The organs which belong to the greater, or, to the systemic circulation, are, the left ventricle of the heart; the aorta and its numerous branches; the different veins of the body, which ultimately unite into three trunks, the superior cava, inferior cava, and the coronary vein; and, lastly, the right auricle. By the assistance of these parts, the blood is distributed to all the organs of the body, from which, having accomplished their nutrition, and being now deteriorated in quality, it is again returned to the heart. The organs of the lesser or pulmonic circulation, comprehend the right ventricle of the heart, the pulmonary artery, the four pulmonary veins, and the left auricle. These structures carry the dark blood to the lungs, and, after it has undergone the requisite changes, they bring back that fluid, now of a scarlet colour, to the left side of the heart.

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* It was not till the year 1628 that Harvey published his celebrated work, "Exercitatio Anatomica de Motu Cordis et Sanguinis." But he had made known his discovery several years before, in a course of lectures delivered at the College of Physicians.

This mode of regarding the circulation was universally adopted, until Bichat founded another division, which is supported upon physiological principles. It is well known that the blood which is contained in the veins of the body, in the right cavities of the heart, and in the pulmonary arteries, is of a dark colour; while that which moves in the pulmonary veins, in the left cavities of the heart, and in the arteries of the body, is of a bright red or vermilion hue. It was according to this difference of colour that Bichat proposed to divide the circulation into two parts:—1. The circulation of the red blood, by which the nutritive fluid is carried from the lungs to every part of the body. 2. The circulation of the black blood, which returns the blood from all parts of the body to the lungs.* The first circulation commences in the minute radicles of the pulmonic veins, and terminates in the ultimate divisions of the arteries of the body: the second begins in the smallest branches of the veins and ends in the capillary vessels of the pulmonic artery.

Both these divisions are founded upon just principles, and each of them may be advantageously employed in studying the various operations of the animal economy.

The general arrangement and the texture of the three component parts of the vascular system, present so many points of resemblance that it will be advisable to consider, in the first place, the properties which are possessed in common by the arteries, the veins, and the lymphatics, and afterwards to describe their individual characteristics.

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* Anat. Gen. t. i. p. 245.

PART FIRST.

SECTION I.

OF THE VESSELS IN GENERAL.

THESE organs, which are so important that any injury inflicted upon them, produces serious, or even fatal consequences, are defended, as far as it is practicable by their situation, from external violence. The great vascular trunks are securely lodged in the cavities of the body, or in the deep parts of the limbs; they take their course in the neighbourhood of the bones, and turn along these in such a manner that, with a few exceptions, they pass over the articulations in the direction of flexion. Many of the veins and lymphatics deviate from this disposition by being placed immediately under the skin; but the vessels which are thus situated are not of any considerable magnitude, and in addition, they are of secondary importance when compared with arteries of a similar size.

The form of the vascular system, taken collectively, is usually compared to that of a tree; the trunk of which is formed by the heart, and the branches by the innumerable ramifications which are lodged in the substance of the various organs. This disposition is more apparent in the blood-vessels than in the lymphatics, although the principle strictly applies to the latter canals.

In conformity with this arrangement, the vessels divide and subdivide as they pass from the heart, becoming gradually smaller, till at length the branches are so extremely minute that they escape the observation of the naked eye. Although the calibre of the vessels decreases in proportion as they are distant from the heart, it is important to state that this diminution affects the branches *individually*, and not *collectively;* for it has been ascertained that the aggregate volume of the branches exceeds that of the trunks from which they proceed. Thus the united capacity of the two common iliac arteries surpasses that of the aorta; and again, the united area of the two subclavian veins is greater than that of the superior cava.

The number of the divisions which occur in the different vessels, is liable to considerable variation; but as Haller and Bichat have stated, it seldom happens that any vessel offers more than twenty successive divisions, from its commencement to its last ramifications.

Each vessel is generally considered to be cylindrical in figure, but Mr. Hunter, who performed several experiments upon this subject, states that the arteries are conical, the narrow end of the cone being placed towards the heart;* we may therefore regard the vascular system as representing a cone, not merely in its totality, but also in its individual parts.

The mode according to which the branches proceed from their trunks, varies in the several regions of the body. In some places the vessels bifurcate, and thus terminate in two branches, as in the bifurcation of the aorta, of the common iliac artery, of the common carotid, &c. A similar disposition is occasionally observed in the venous system, in which, however, the connexion is traced in the opposite direction, or from the branches towards the trunks; this is seen in the formation of the inferior cava by the junction of the two common iliac veins. The same arrangement also exists, but in an inferior degree, in the absorbing system.

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* Treatise on the Blood, vol. i. p. 297.

The angles which the vessels form in dividing are of various sizes, although they are generally more or less acute, approaching, according to Haller, the measurement of 45°. The vessels of the extremities divide into branches at a small angle, and the spermatic arteries and veins are connected with the aorta and inferior cava respectively, at still more acute angles. In the chest, in the abdomen, and occasionally in the limbs, the large vessels form with their trunks, angles which approach 90°; this is the disposition of the great arteries which arise from the arch of the aorta; also of the intercostal, the cœliac, the articular, the tarsal arteries, &c. A similar arrangement is observed in the terminations of the renal, lumbar, and internal jugular veins; and likewise in the junction of the thoracic duct with the subclavian vein. It occasionally happens that the angles of division are obtuse, as in the instances of the upper intercostal and coronary arteries. In some more rare examples, the angle is so open, that the vessels are recurrent, as in the spinal arteries, and in the recurrent vessels of the different articulations. It has, however, been well observed, that those branches which appear to form obtuse angles with the trunk, come off in reality at acute angles, and that it is only from their immediately forming an inflexion and altering their course, that they have the appearance of arising at a large angle.

There are but few general principles that can be deduced from the preceding observations concerning the divisions of the vascular system. It is evident, however, that as this system is disposed in the form of a cone, of which the apex corresponds to the heart, the blood, as it passes from that organ towards the distant ramifications of the arterial system, must circulate in a space which gradually enlarges; and on the contrary, that the contents of the veins and absorbents must be propelled through channels which successively decrease in size as they approach the heart. It was also remarked by Mr. Hunter, that in the vicinity of the ventricles the arteries arise at large angles, by which mechanism the force of the circulation is diminished; while at a distance from the heart, the branches form very small angles with their trunks, so that there is but little opposition to the free current of the blood.

ANASTOMOSIS OF VESSELS.

The various parts of the vascular system freely communicate in all parts of the body, by means of what are called *anastomosing branches*. This arrangement is more developed in the lymphatics and veins than in the arteries; the communications are also more frequent in the small than in the large vessels, although they are often observed between trunks of considerable magnitude.

1. The most ordinary species of anastomosis is that which results from the union of two vessels in the form of an arch; this disposition exists in the vessels of the mesentery, mesocolon, and kidneys; it is also met

with around the joints, and generally in all the smaller vessels of the body.

2. The second kind of communication is established by means of large and usually short branches which extend between two neighbouring trunks. Such are the anastomoses of the two anterior cerebral arteries with each other, and of the internal carotid with the posterior cerebral, where they form the circle of Willis; of the two umbilical arteries at their entrance into the placenta; of the umbilical vein with the inferior cava by means of the canalis venosus; and, lastly, of the superficial veins and lymphatics of the extremities.

3. The last species of anastomosis, is common in the venous and lymphatic systems, but very rare in the arterial; it is produced by two vessels uniting at an acute angle in order to form a third. There are many examples of this disposition in the veins and lymphatics of the extremities and trunk; and also in the union of the two vertebral arteries where they form the trunk of the basilar, and of the two anterior spinal arteries.

The connexion by anastomosing branches, is generally established between neighbouring vessels; but there are instances of communications being formed between very distant trunks. Thus the subclavian and iliac arteries are united by means of the internal mammary and epigastric arteries; and the inferior and superior venæ cavæ communicate by the vena azygos.

Many circumstances influence the freedom of anastomosis in the different parts of the vascular system. In the first place the communications become more frequent in proportion to the minuteness of the vessels, and their distance from the heart. This fact is rendered very evident by examining any transparent part of a living animal with the microscope, when it is seen that the small vessels form a most intricate plexus, in which the fluids circulate with amazing facility. The situation and the degree of exposure to which the vessels are subjected, affect, in a striking manner, the number and size of their inosculations. Thus, the blood-vessels and lacteals of the mesentery, which are continually influenced by the action of the abdominal muscles, and by the peristaltic motion of the intestines, are pre-eminently distinguished by the multitude and volume of their anastomosing branches. Again, in the extremities, the articular arteries freely communicate, because they are necessarily compressed in the movements of the joints; and, for a similar reason, the superficial veins and lymphatics, which are exposed on the surface of the body, unite with each other more frequently than the deeper-seated vessels. There is still another circumstance that has a decided effect on the freedom of anastomosis: I allude to the importance of the organ to which the vessels are distributed. The brain affords a remarkable illustration of this statement: it is well known that, at the base of this organ, the arteries are joined to each other by the large branches which constitute the circle of Willis.

Nature appears to have employed two methods for securing the circulation of the different parts of the body; the first, and the most essential, is the anastomosis of the vessels; the second, which ought, perhaps, to be regarded as subservient to the former, is the transmission of the fluids which belong to any particular region or organ, through two or more channels, instead of through one trunk. The latter provision is exemplified in the fore arm, which possesses four principal arteries, with corresponding veins and lymphatics; and it is even more striking in the brain, which receives its blood through four totally independent canals.

The powers of the anastomosing circulation are capable of being increased to a surprising extent, whenever there is any interruption to the ordinary flow of the circulating fluids.* I shall merely adduce the following proofs in support of this position. The aorta has frequently been tied in animals of considerable size with perfect success; it has also been found entirely obliterated in different parts of its course, in the human subject; in one case the closure occurred as high as the termination of its curvature. Many cases are related in which the inferior cava, the internal jugular, and the iliac veins, have been obliterated; and Dr. Hunter has recorded a case, in which the superior cava and the left subclavian vein were almost closed by the pressure of an aneurismal tumour. Lastly, the trunk of the thoracic duct has been tied by Flandrin, Dupuytren, and others, and several of the animals recovered. It ought to be stated, however, that the last named distinguished physiologist has discovered, that in the animals which survived, it was possible to inject quicksilver from the abdominal portion of the duct into the subclavian vein, the mercury passing through some large lymphatic vessels, which proceeded from below the ligature and opened in the vein of the neck.*

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* It was upon this principle that the modern operation for aneurism was performed in the year 1785 by Mr. Hunter, for the cure of an aneurism in the ham. Subsequently to this grand improvement, the external iliac has been secured by Mr. Abernethy; the subclavian artery below the clavicle, by Mr. Keate; the common carotid, by Sir A. Cooper; the subclavian artery above the clavicle, by Mr. Ramsden; the internal iliac artery, by Dr. Stevens; the arteria innominata, by Dr. Mott, of New York; and lastly, the abdominal aorta itself, by Sir A. Cooper. This list of distinguished names is one among the many gratifying proofs which might be mentioned, of the great benefits that have been conferred on mankind by the talents and labours of English surgeons.

The reader is referred for a very excellent account of the anastomosing communications of the arteries belonging to the upper and lower extremities, to the Treatise on Aneurism, by Scarpa, translated by Wishart, p. 1, et seq.

It is almost needless to add, after what has been stated, that the great use of anastomosis is to facilitate the circulation of the fluids, by preventing any interruption to their current in the various organs of the body.

The vessels, and particularly the trunks, generally pass in a straight direction, so that their course more or less corresponds with the long axis of the body; there are, however, many deviations from this disposition. The small vessels do not observe any constant arrangement, although in most places they present an arborescent or reticulated appearance. The arteries belonging to organs which are subject to considerable changes in their volume, figure, or situation, are distinguished by the flexures they describe in their course; there are examples, in the vessels of the uterus during the enlargement of that viscus in pregnancy, in those of the stomach, the intestinal canal, the lips, tongue, &c.

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* The most remarkable instance I am acquainted with, of the powers of the anastomosing circulation, occurred in a dog on which my late brother, in the presence of several of his friends, performed the following experiments. He first tied the abdominal aorta, and when the animal had recovered from that operation, he secured, at intervals, the carotids and the great trunks of the anterior extremities, so that the whole course of the circulation must have been altered. The dog, which was of very large size, survived all these operations and appeared to enjoy its ordinary health. It unluckily happened, that this animal was at Birmingham, when an alarm of hydrophobia prevailed, and, owing to negligence, it escaped into the streets, and was, in all probability, destroyed by some of the people, who had orders from the magistrates to kill all dogs found abroad. Although many attempts were made to discover the body, they were unsuccessful; so that there was no opportunity of ascertaining by what new channels the circulation was carried on.

The vessels of the brain and spleen are extremely tortuous, by which disposition the current of the blood is materially slackened.* In the extremities, the natural elasticity of the vessels makes up for the deficiency of those curvatures, which are met with in the vascular system of the head and abdomen.

The vessels are nearly symmetrical,† although there are many exceptions to this observation. The want of symmetry is particularly evident in the great vascular trunks; as the aorta, arteria innominata, cœliac axis, venæ cavæ, thoracic duct, &c. On the contrary, in the head, neck, and extremities, the vessels on the two sides of the body nearly correspond.

The course of the different vessels is subject to great variation as to its extent, but generally the branches proceed from their trunks, in the neighbourhood of the organs to which they are distributed. In a few instances a contrary disposition is observed; thus the spermatic vessels take a long course before they reach their destination; but even in these cases the contradiction is rather apparent than real, and is readily explained when it is recollected, that the testes and ovaria are placed in the fœtus near the aorta and the inferior cava, with which the spermatic arteries and veins are respectively connected.

The number and the size of the vessels, and, consequently, the quantity of fluid which they carry, are extremely unequal in the different structures of the body. It rarely happens that an organ does not receive several vessels, which frequently are derived from distinct trunks, and which usually divide and anastomose with each other previous to terminating. The bodies that are situated on the median line, receive two vessels of the same name, the one right, and the other left; this is seen in the brain and spinal cord, in the nose, tongue, larynx, bladder, penis, &c. Some of these organs have more than two vessels, thus the brain and thyroid gland possess four each, and the spinal cord receives a great number of branches from the arteries of the neck, chest, and abdomen. The bones, muscles, nerves, glands, &c. are also supplied by several arteries which penetrate by different points of their surface. On the contrary, the spleen, the kidney, and the eye, only receive one artery and one vein.

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* It appears, that the tortuousness observed in certain vessels, depends, in some cases, on increased local action; and in others, on the obstruction which is offered to the free circulation of the contained fluids. The influence of the former cause is exhibited in the changes which the uterine arteries undergo during gestation; and that of the latter, in the production of varicose veins in the legs.

† See p. 19.

The arteries, veins, and lymphatics, after they have entered the substance of the organs, divide and subdivide, till at length they become so extremely minute that they escape the naked eye. If the microscope is employed, it will be seen that the small branches still continue to divide, and that ultimately they form by their communications a very beautiful and intricate plexus. The termination of the vessels offers so many important points for investigation, that I shall defer the consideration of the subject until the properties of the arterial and venous systems have been described.

SECTION II.

ORGANIZATION OF THE VASCULAR SYSTEM.

THE blood-vessels and lymphatics are composed of certain layers or tunics, the number and character of which vary considerably in the three orders of vessels. In the present day it is admitted that the arteries and veins possess three coats, but with respect to the absorbents, they have only two membranes.

The *internal coat* is the most important, because it extends throughout the vascular system, and although in the different divisions of this system modifications may be observed in its structure, yet it appears to possess in all parts essentially the same properties. It is very thin, whitish, and almost transparent; when examined with the naked eye there is no appearance of fibres, nor have I been able to detect any with the microscope. Dr. Hodgkin and Mr. Lister state, however, that the internal membrane of the arteries consists of extremely delicate, smooth, and uniform fibres, which are tortuous and matted together in an intricate plexus. In proportion to its thickness this coat is very dense and resisting, so that it is capable of supporting by itself a considerable column of quicksilver; it is also extensible and elastic.

The inner surface of the lining membrane is perfectly smooth, and is moistened by a thin and rather unctuous fluid, which has a great resemblance to the secretion of the serous membranes. It is an interesting question to determine what is the source of this liquid. Is it formed like the fluid of the peritoneum and similar structures, by a secerning process during life; or is it produced after death, as Bichat is inclined to believe, by a transudation like that of the bile through the gall bladder? Or, again, does it merely consist of a small quantity of serum that remains in the vessels after the expulsion of the blood? A careful examination of this tunic, both in its healthy and morbid states, has convinced me that it is very analogous to the serous membranes. In its natural condition it has a glistening and shining appearance, which I believe is never presented by any surface that is not habitually moistened by a secreted fluid. Innumerable cases are related by writers on surgery, which prove that the lining coat is very liable, like the serous membranes, to the adhesive form of inflammation; thus when the arteries, veins, or lymphatics are inflamed, fibrin is frequently poured out on the inner surface, and the tubes become closed, or, in fatal cases, flakes of the effused matter are observed in the vessels. The same effect is also produced when arteries are secured with the ligature, or are wounded by accident.

The external surface is united to the next coat, from which, however, it may be separated without difficulty, particularly in the arteries.

The internal tunic assists in the circulation, by furnishing a polished surface, along which the blood and lymph readily flow; and, by its density, it prevents the escape of the contained fluids out of their proper channels. It also forms, in many parts of its extent, particularly in the veins and lymphatics, semi-lunar folds, which are distinguished by the name of *valves*.

The second or *middle coat* is very evident in the arteries and in the large veins, but it is not distinct in the smaller veins, and in the absorbing vessels it cannot be perceived. This tunic is composed of a peculiar fibre, which is considered by many anatomists to be muscular, while others regard it as being formed of a peculiar substance, which is called by the French writers, the *yellow* or *elastic tissue.* The fibrous membrane is opake, firm, elastic, and brittle; it is of a yellowish colour in the arteries, and reddish brown in the veins. It has few properties in common in the two systems, but in both it is endowed with a contractile power, which enables it actively to assist in the circulation of the blood.

The *external coat,* also called *cellular*, *elastic*, &c., exists, under various modifications, in most parts of the vascular system. It consists of condensed and fibrous cellular substance, which has a yellowish white colour; it is remarkably elastic, and by its firmness it gives to the vessels the principal part of their strength in the longitudinal direction. Scarpa contends that this covering ought not to be considered amongst the component parts of the vessel; he says that it is merely an adventitious sheath, furnished by the common cellular membrane, which keeps the vascular organs in their situation, and connects them with the surrounding parts.* This opinion is incorrect, for a careful inspection of an arterial trunk, shews that the elastic coat is distinct from the loose cellular tissue by which it is united to the neighbouring organs, although, as elsewhere, there is a general connexion between the two parts. The internal surface of the elastic tunic is dense, and so closely joined to the middle coat, that it is very difficult to separate one from the other; it is indeed supposed by Bichat, that in the arteries the fibres of the latter coat are inserted into the former.*

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* Treatise on Aneurism, p. 69.

The blood-vessels and lymphatics, like all other organs of the body, are provided with proper vessels, which are called the *vasa vasorum.* The small nutrient arteries arise from the neighbouring branches, and rarely, if ever, from the vessel itself to which they are distributed. They may be distinctly seen ramifying in the loose cellular substance that covers the larger vessels; they afterwards penetrate to the fibrous coat in which they principally appear to terminate, although there is no doubt that the most delicate branches extend to and supply the internal membrane. The presence of lymphatics is assumed rather from what happens in disease, than from any actual demonstration of their existence. It is said that they have been observed with the microscope, and also that they may be injected. In many morbid states of the vascular system, their action is rendered very apparent; thus the internal tunic is occasionally destroyed by ulceration; and again, when an artery has been tied, the ligature is detached by a similar process affecting the external coat.

The nerves of the vessels are numerous, although, from their small size, they cannot be traced, except on the large branches. It it generally supposed that the nervous supply is derived principally, or entirely, from the ganglions of the great sympathetic; but it is certain that the nervus vagus furnishes filaments to the pulmonary vessels, and it appears that in the limbs the nerves are derived, at least in part, from the cerebro-spinal system.

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* Anat. Gen. t. i. pp. 271 and 286.

I shall conclude these observations by stating, in the words of a most intelligent and judicious writer, that "the arteries (*and also the veins and lymphatics,*) are supplied not only with small arteries and veins, but also with absorbents and nerves, and have, in these respects, a similar organization to the other soft parts of the body. This structure makes them susceptible of every change to which living parts are subjected in common; enables them to inflame when injured, and to pour out a coagulating lymph, by which the injury is repaired, or the tube is permanently closed.*

The properties and functions of the vessels will be separately considered in the articles on the arterial, venous, and lymphatic systems.

SECTION III.

DEVELOPMENT OF THE VASCULAR SYSTEM.

THE vascular system, like all other parts of the animal body,† attains its full perfection only by degrees, and as its organization is very complex, it presents diverse appearances in the successive stages of its development, some of which bear a strong resemblance to the circulating organs of the inferior animals. Several modern physiologists, amongst whom may be mentioned Home, Rolando, and Serres, have endeavoured to ascertain the laws according to which the formation of the heart and blood-vessels is regulated. I shall, in the following observations, principally avail myself of the luminous account of this process, which has been published by Professor Meckel.*

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* Dr. Jones on the Proc. employed by Nature in suppressing Hæmorrhage, p. 5.

† See p. 77, p. 81.

In tracing the changes that occur in the vascular system, there are four principal points which it is desirable to determine: 1. The order according to which the different parts of this system first appear. 2. The arrangement which these parts observe at their primitive origin. 3. The relation which exists at different periods between the organs of the greater and lesser circulation. 4. The proportion between the number and capacity of the different orders of vessels in the several epochs of life.

1. In attempting to ascertain what part of the vascular system is first developed, we are obliged to judge rather from the phenomena that occur in the process of incubation, than from any positive observations that have been made in man, or in the mammiferous animals. It may be stated, with tolerable certainty, that the veins of the *vesicula umbilicalis*, which in the human ovum corresponds with the membrane of the yolk, or *vitellary sack* of the incubated egg,† are the first which become apparent. The exact nature of the connexion that exists in the beginning, between the umbilical vesicle and the embryo, is rather obscure, but it is supposed that the cavity of the former communicates with the intestinal canal of the latter. It is evident that up to the second month the vesicle is connected by an artery and a vein,

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* Man. d'Anat. t. i. p. 142, *et seq.*

† The analogy of the vesicula umbilicalis with the tunica erythroides, which is seen in the ova of some mammalia, was originally observed by Blumenbach. This umbilical vesicle has been frequently, but incorrectly compared to the allantoid membrane of quadrupeds.

with the vessels of the mesentery; these communicating vessels are therefore called *vasa omphalo-mesenterica.*[*]

2. The vessels of the incubated egg first appear under the form of minute vesicles, or rather of rounded spaces which are formed in the vitellary membrane, and which are filled with a viscid fluid. These spaces are at first isolated and distinct from each other; but gradually increasing in number, they constitute a very ramified vascular network, which soon contains real blood. The minute vessels of this plexus unite, and at length form the trunk of the omphalo-mesenteric vein. These vessels, in their origin, do not possess distinct parietes; they are, in fact, merely canals hollowed in the substance of the yolk-bag; but insensibly this membrane becomes thickened around the canals, and thus forms the rudiments of their walls, which are progressively, but slowly, perfected.

3. The omphalo-mesenteric vein being thus formed, passes from below upwards, and terminates in a vein which, ascending perpendicularly, is dilated at the point where the heart is ultimately formed. The aorta arises from this dilatation, and, by its branches, distributes blood to the different organs; the corresponding veins, and also the omphalo-mesenteric artery, appear nearly at the same time. It is most probable, that the umbilical vessels are developed in the same order as the omphalo-mesenteric, which they seem to supplant; that is to say, the vein first and the arteries afterwards.

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[*] A conjecture has been offered by Meckel which, in part, is opposed to the above description. He thinks it is probable, from the examination of the vascular system in acephalous monsters, and from the mode in which this system is formed in the animal kingdom, that the aorta is developed at the same time with the veins, or even before them.

The omphalo-mesenteric vein opens into the mesenteric vein of the embryo, and in this manner communicates with the vena portæ. The latter vessel, at this period, constitutes the principal trunk of the venous system, and has, at its superior extremity, an enlargement which corresponds with the situation of the heart. This organ appears in the form of an imperfect ring, the left ventricle being the part first observed, and immediately afterwards the aorta is seen, having the appearance of a considerable dilatation; at a rather later period, the auricle is formed. These vesicles, which are separated for a time, subsequently approach each other and unite so as to form two small cavities, an auricle and a ventricle, each of which in the sequel becomes double. Whilst these changes are proceeding, the other parts of the vascular system are advancing in their growth. The vena portæ, which originally lies behind the liver, becomes connected with the umbilical vein, and the two vessels then ramify in that organ and thus communicate with the hepatic veins. A trace, however, of the original course of the vena portæ remains during the life of the fœtus; this vestige is the *canalis venosus*, which extends from the umbilical vein and vena portæ to the inferior cava. In some instances, from an interruption of the formative process, the primitive disposition of the vena portæ even continues in after-life, the trunk of that vessel passing behind the liver and terminating directly in the inferior cava.

In proportion as the development of the heart proceeds, the auricle becomes divided by an imperfect septum, which permits a free communication between the two cavities, through a large opening, called the foramen ovale. The division of the ventricle is effected in a different manner: the right ventricle, which at first has the form of a small tubercle, gradually extends towards the apex of the heart; it communicates for some time with the left ventricle, so that, in the principle, the aorta is connected with both ventricles. The pulmonary artery, which is the last of these central parts that presents the form of a distinct trunk, arises, in the first instance, from the aorta, and, after the two vessels are separated from each other, they still communicate by means of the *canalis arteriosus*, and continue to do so during the whole period of the fœtal life. The pulmonary artery does not possess any branches till the eighth week, when two may be discovered passing to the lungs.

The peculiarities which have been briefly pointed out in the preceding remarks, have a very striking influence on the circulation of the blood. The fœtus derives its support, during the greater part of its existence, from the mother, through the medium of a peculiar structure, which is termed the *placenta*. The umbilical vein, arising by numerous branches from this body, passes in the umbilical cord to the abdomen of the fœtus, and from thence to the longitudinal fissure of the liver. The vein having reached this point, distributes many branches to the left lobe of this organ, and at the transverse sulcus it forms a direct communication with the vena portæ, so that the blood of the two vessels is mixed together, and afterwards circulates in the liver, from which it is returned by the hepatic veins. It is calculated that four-fifths of the fluid carried by the umbilical vein, are distributed to the liver, the remaining fifth being transmitted directly to the inferior cava, by means of the canalis venosus. The blood arriving at the right auricle, from the inferior cava, passes principally through the foramen ovale, into the left auricle; but a portion of it mixes with the blood, which is returned to the right side of the heart by the superior cava, and the two streams are propelled into the right ventricle, and from thence into the pulmonary artery. The larger portion of the fluid that enters this vessel is directly conveyed into the aorta, through the canalis arteriosus; the remainder is distributed to the lungs, and is subsequently returned to the left auricle by the pulmonary veins. In this cavity the current from the lungs mingles with that which passes through the foramen ovale; this common mass of blood is then driven into the left ventricle, and, by the contraction of this cavity, it is forced into the aorta, where it meets with that portion of blood which traverses the arterial canal.

The aortic circulation in the fœtus bears a considerable resemblance to the same circulation after birth; by its agency the blood is carried into all parts of the body, and is afterwards returned through the ordinary course of the venous system. There is, however, one great peculiarity that it is essential to notice; each internal iliac trunk gives off a great vessel, called the *umbilical artery*, by which channel the larger part of the blood that is contained in the abdominal aorta is sent to the fœtal portion of the placenta.

It has been said by many writers, that the blood which ascends from the inferior part of the body to the right side of the heart, is, by the mechanism of that organ in the fœtus, almost entirely distributed to the head and upper extremities; and, on the contrary, that the blood, which is brought back by the superior cava, is transmitted into the descending portion of the aorta.

I believe, however, that the peculiarities, which really exist in the circulation through the heart and great vessels, have been exaggerated, and certainly cannot justify the statement of Bichat, that the blood before birth describes two circles which intersect each other, so as to describe the figure 8.

The peculiarities of the circulation of the fœtus have evidently a reference to its dependent mode of existence. Thus the nutritious fluid requires to be carried to and from the mother, a circumstance which explains the necessity of the umbilical blood-vessels; and again, as the placenta supplies the office of the lungs, there is no occasion for the blood to pass to those organs, and hence the provision of the foramen ovale and canalis arteriosus. In proportion as the fœtus approaches the term of its existence, the mechanism of the vascular system resembles that which is required for the support of extra-uterine life.

4. The capacity of the vascular system and the number of the vessels, exhibit many variations in the different periods of life. The heart of the embryo is larger when compared to the body, in proportion as it is examined early after impregnation. The relative volume of the two sides of this organ also varies in the adult, the right side always exceeding the left, and the parietes of the latter greatly surpassing in thickness those of the former; in the fœtus, on the contrary, the two ventricles are nearly equal in size and in thickness. The most striking differences, however, are observed in the vessels. In the child every part is more abundantly supplied with these organs than at a later period. In old age the number of the smaller vessels is not only considerably decreased, but the structure and capacity of

the large ones are very much altered; the arteries are rendered more dense, and being frequently thickened and ossified, their calibre is diminished; the veins on the contrary, although their texture is deteriorated, are considerably dilated. These changes in the condition of the blood-vessels, are readily demonstrated by the effects which are produced by injecting subjects of various ages.

PART SECOND.

SECTION I.

OF THE ARTERIES.

THE arterial system consists of numerous flexible and ramifying tubes, *arteriæ*, which convey the blood from the heart to all parts of the body. These vessels derived their name from the ancients, who seeing them empty after death, concluded that they contained air or vapour during life.

The arteries proceed from two great trunks, which are immediately connected with the cavities of the heart: one, the aorta, arises from the left ventricle, and is the common source of the arteries of the body; the second, the pulmonary artery, springs from the right ventricle, and furnishes the arterial tubes of the lungs. The connexion of these trunks with the heart is rather of a peculiar character; the lining membrane of the ventricle is prolonged into the corresponding artery, and thus constitutes a direct union between the two parts. When this membrane is carefully raised, it is seen that the proper, or fibrous coat of the artery, which is in no manner continuous with the fleshy parietes of the heart, is at the beginning divided into three semicircular festoons, which correspond to the sigmoid valves, and leave between them as many small triangular spaces. The borders of these festoons are firmly attached to the orifice of the ventricle by a quantity of ligamentous tissue, and a similar substance fills up the triangular intervals just described.

The arteries present, like the vascular system in general, an arborescent form, the branches successively diminishing in size and increasing in number, as they pass from the heart towards their ultimate termination. Each trunk usually ends by dividing into two or more branches, the size of which may be either equal or unequal; but whatever be their relative capacity to each other, it is found that with few or no exceptions, their combined area is greater than the area of the vessel from which they spring. The ratio of this excess being liable to great variation, cannot be determined with any precision; but, according to Haller, the capacity of the branches exceeds that of the trunks whence they proceed, in the proportion of 1½ to 1, or rather less.

SECTION II.

ORGANIZATION OF THE ARTERIES.

THE arteries, after they are emptied of their contents, are of a whitish or yellowish colour; and they present on their external surface a loose and flocculent appearance, whilst their inner surface is every where perfectly smooth and polished. When one of these vessels is cut across, its parietes seem to be homogeneous; but on a closer examination it is evident, that they are composed of several laminæ superposed on each other and intimately united by delicate cellular tissue. Each of these layers, which are three in number, possesses a peculiar texture and has a separate function to perform in the circulation of the blood.

The *internal membrane*, called also the *arachnoid*, *common*, &c., lines the whole extent of the arterial system; but the portion which belongs to the pulmonary artery is distinct from that connected with the aorta, and as it is continued from the interior of the right ventricle, it may be appropriately considered with the structure of the veins. The lining tunic is very thin, and almost colourless and transparent; it is harder, more fragile, and more elastic than the same membrane in the other parts of the vascular system. It is not susceptible of much extension, and is so firm and resisting that after the other coats of an artery have been entirely removed, in a living animal, it is capable of resisting the impetus of the circulation, and of preventing dilatation of the artery.*

If a large artery be slit open, some longitudinal folds may be observed on its internal surface, and in a vessel which is placed in the bend of a joint, as the popliteal artery, a few small transverse lines may be perceived. At the commencement of the aorta, and also of the pulmonary artery, the internal membrane forms three large folds which are called the *sigmoid* or *semilunar valves;* each of these is fixed by its convex border to the circumference of the artery, close to the margin of the osteum arteriosum; the opposite or superior edge is free in the cavity of the vessel, and possesses in its middle a small fibro-cartilaginous nodule, which is called the *corpusculum sesamoideum.* The walls of the arteries are dilated opposite to the valves, and thus constitute the *sinuses* of the aorta and pulmonary artery. These folds are so disposed that they permit the free passage of the blood from the heart towards the vessels, but they entirely prevent the return of the fluid by closing up the arterial aperture.

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* See an account of two experiments performed by Mr. Hunter and Sir E. Home. Trans. of a Society for Imp. of Med. and Chir. Know., vol. i. pp. 144 and 145.

The *middle* or *fibrous coat*, which has also been termed *muscular tunic*, *proper membrane* of the arteries, &c., has commanded great attention, in consequence of its importance. It is composed of yellowish and flattened fibres, all of which pass in a circular, or, strictly speaking, in rather an oblique direction around the calibre of the artery; they appear not to form complete circles, but to consist of segments which are joined so as to produce rings. These fibres form several layers, which may be easily raised by the forceps, especially in the great trunks; this circumstance has deceived many writers, by causing them to think that the large arteries possessed a great number of tunics. The fibrous coat is proportionally thicker in the small vessels than it is in the trunks, but as Mr. Hunter has observed, it is difficult to make an accurate comparison in this respect between the different parts of the arterial system. The thickness of this tunic is also subject to variation in the vessels of different organs; it has been long remarked, for example, that the arteries of the brain, and particularly the internal carotid, are provided, in proportion to their size, with a very thin fibrous coat; indeed, some authors formerly went so far as to deny its existence in those vessels.

The fibrous coat which is firm, solid, and elastic, is at the same time very brittle, so that it is readily divided by the ligature. According to the analyses of Berzelius and Dr. Young, it contains no fibrin. In these respects it differs from the characters of proper muscle, to which it is often compared.

Bichat, who has distinguished himself by denying the muscularity of the arteries, has brought forward many facts, which he conceives prove the truth of his opinion; but some of his objections are trifling, and several of the comparisons that he has made between the muscular and arterial structures, are founded on fallacious grounds.* This subject requires further investigation before it can be satisfactorily determined; but it is certain that the arteries, whether they possess a proper muscular structure or not, are endowed with the capability of contracting on their contents, and that this contractile power can be excited by mechanical and chemical stimulants.

The *external*, or *elastic coat*, consists of small whitish fibres, which are very dense and tough, and interlaced together in every direction. The outer surface of this membrane is covered by an extremely loose and flocculent cellular substance, which connects the artery to the surrounding parts, and particularly to the sheath of the vessel; the cells of this tissue are filled in the early period of life by a serous fluid, and in advanced age by an oily matter. Many writers have erroneously described this substance as a distinct cellular coat, placed externally to all the others; but it is evidently nothing more than the common connecting cellular membrane.

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* I shall mention one of the experiments which was performed by Bichat to disprove the muscularity of arteries: if a ligature be applied tightly around an artery, it causes a complete division of the middle, and also of the internal coat; now if a thread be tied in a similar manner around a portion of intestine, the muscular coat of the gut will be compressed, but not divided. This is a very unsatisfactory experiment, because in the first place, the muscular fibres of the intestine are not disposed in the same order as the fibres of the middle coat of the artery, notwithstanding the contrary statement of Bichat, for in the intestine there are *longitudinal* fibres which are entirely deficient in the artery; in the second place, the thick and soft mucous coat of the intestine must modify the operation of the ligature on the muscular coat. See Anat. Gen. t. i. p. 273.

The external coat is proportionally thicker in the large than in the small arteries, being in this respect opposed to the fibrous membrane; its thickness is also liable to variation in particular vessels; it is, for example, very thick on the convexity of the curvature of the aorta, whilst in the branches of the internal carotid and vertebral arteries, it is almost as thin as paper.*

This membrane is distinguished by its great resistance and elasticity, especially in the longitudinal direction; its firmness is so great, that it is not divided by the application of the ligature.†

It has been shewn in the preceding part of this chapter, that the arteries are provided with proper nutritious vessels, and also with nerves. It is only necessary to state in addition, that the vasa vasorum of the arteries are of immense importance in a surgical point of view; and that each individual part of an artery is supplied by its own appropriate vessels, which form but few communications with those above and below. It is therefore essential, in tying any arterial trunk, to disturb it as little as possible, and only to expose so much of it as is precisely required for the proper application of the ligature.‡

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* Gordon, Sys. of Anat. p. 60.

† Jones, Treatise on Hæmorrhage, p. 3.

‡ The terrible mischief which results from detaching the artery farther than is actually required, is illustrated by the history of Mr. Hunter's first cases, and of others, where the *ligature of reserve* was employed. In these

The nerves of the arteries are so very small, that they are traced with difficulty; they penetrate to the fibrous coat, to which it appears they are principally distributed.

SECTION III.

PROPERTIES AND FUNCTIONS.

THE resistance of the arteries after death in the longitudinal direction, which almost entirely depends on the external coat, is very great, as the following experiment performed by Dr. Gordon, will prove:—A portion of the common carotid was removed from a man twelve hours after death, and it did not give way till a weight of 30 lbs. avoirdupois was attached to it. The strength of the artery in the transverse direction, cannot be ascertained with any precision, because it is mainly owing to the fibrous tunic, which loses much of its force after death; it must, however, be considerable, for the arteries, even near the heart, so powerfully resist the influence of the ventricle, that little or no dilatation can be perceived in them during the systole of that cavity.* Scarpa has stated, that the internal coat, although thin, is that which opposes more than either of the others, the bursting or preternatural dilatation of the arterial tube; but he does not appear to have made proper

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instances, the vasa vasorum being destroyed, the artery, deprived of its nourishment, sloughed or ulcerated, and thus caused serious or even fatal secondary hæmorrhage. For some important observations on this subject, see, amongst other writers, Hodgson, Treatise on Diseases of Art. and Veins, p. 214, *et seq*. Scarpa, by Wishart, Treat. on Aneurism, p. 268, *et seq*.

* Dr. Caleb Parry, Experim. Inquiry, p. 107, *et alibi*.

allowance for the power which is possessed during life by the fibrous coat.

The force of resistance is generally in proportion to the thickness of the coats. Wintringham, indeed, who made many experiments and minute calculations on this subject, concluded that the thinnest and smallest vessels are proportionally stronger than others, which are superior in capacity and thickness;* but there is reason to doubt the exactness of his investigations.

The arteries are capable of being extended, especially in the direction of their length; thus, if an artery be tied in two places, and divided between the ligatures, the portion which is next the heart is sensibly elongated at each systole of the ventricle. Again, if a portion of an artery be cut out from the dead body, and is then stretched, it becomes much lengthened; after yielding extensively without rupturing, it begins to tear, the internal coats giving way first, and subsequently the external membrane, having been greatly elongated, is lacerated. The extensibility in the circular or transverse direction is very inconsiderable; it is seen in those cases where the principal trunk of a limb being obstructed, the collateral branches are enlarged; the arteries may also be distended by forcible injection, and in the aneurism caused by dilatation.

The most important of the physical properties is their elasticity. Numerous instances might be adduced to illustrate the effects produced by this power, but I shall confine myself to some of the most remarkable. After an artery has been extended either lengthwise or transversely, it suddenly retracts on itself when the extending force is removed, and thus returns to its original state; if the finger be forcibly introduced into the section of a large artery, the sides of the vessel re-act on the finger and powerfully compress it; if an artery be divided in the dead body, it is seen, that, although emptied of its contents, it preserves its capacity and cylindrical form; indeed its diameter is larger than it was during life, because the constant contraction which is exerted by the fibrous coat being destroyed by death, the elasticity of the vessel dilates it beyond its ordinary size. The elastic property is possessed by all the coats, but not in the same degree, being greatest in the external, and least in the internal membrane; it also varies according to the volume of the arteries, being very much developed in the large trunks, and successively decreasing in the branches.

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* Experim. Inquiry, p. 182, *et seq.*

This power assists in the circulation, but its importance has been exaggerated by many physiologists, who have attributed to this faculty effects which undoubtedly depend upon the action of the fibrous coat. The elastic property affects the artery both longitudinally and transversely; in the former direction, its influence appears to be confined to restoring the vessels to their original state, after they have been elongated in the various motions of the body. It is more difficult to determine the effects of elasticity in the transverse or circular direction, but I believe that its principal use is to keep the arteries patent, and thus to assist in the circulation by facilitating the flow of the blood within those tubes; it will also aid the tonic power of the fibrous coat in resisting the over distention of the arteries.

The consideration of the vital properties of the arterial system, embraces a most extensive field of inquiry, and one that has been a very prolific source of discussion amongst physiologists. But notwithstanding the multiplicity of experiments, which have been performed in order to determine the question, the exact nature of these powers still remains involved in obscurity.

The principal subject of this controversy relates to the existence or non-existence of an active power of contraction in the arteries. This property, which is variously denominated by the terms of the irritability, the tonicity, the contractility, and the vital force of the arteries, has been denied by some anatomists, and admitted by others. The former contend that the arteries are either passive tubes, which receive the blood from the heart, and transmit it, without acting on it, or that they assist in propelling that fluid simply by means of their elasticity. The latter, on the contrary, conceive that the arteries are endowed with an active power, which is either identical with muscular contractility, or consists of a species of contraction which is peculiar to these organs.

The following are the principal objections that have been urged by Haller,* Bichat, and other physiologists against the contractility of the arteries: it is stated that these vessels exhibit no marks of contraction when they are irritated, either on their external or internal surface, by mechanical or chemical agents, and even that no motion is perceived when their fibres are dissected and raised layer by layer; that, if an artery be removed from a living animal, or if a portion be secured between two ligatures, in neither instance is there any appearance of contractility; that, irritation of the nerves belonging to an artery, even when galvanism is employed, does not produce any effect on it; and, lastly, that opium, which paralyses the muscles, has not the same influence on the arteries.

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* It is necessary to state that Haller thought the arteries possessed a certain degree of contractility, which assisted in the circulation. His experiments, however, did not prove the contraction of the arteries, but rather the reverse. —*Mémoires sur la Nature, Sens. et Irrit. des Parties du Corps Anim.* t. i. p. 55.

All these objections have been most satisfactorily controverted by the direct experiments of Verschuir, Hunter, Dr. W. Philip, Dr. Thompson, Dr. Hastings, &c. We learn, from these inquiries, that the arteries, and especially those of small calibre, possess a proper contractile power, which may be excited by various stimulants; by concentrated or diluted acids, by ammonia, by the scalpel, by galvanism, and by simple exposure to the atmosphere. The degree of this contraction is very great, even in the large trunks; thus, Mr. Hunter observed, that the posterior tibial artery, being exposed in a living dog, was so much contracted in a short time as almost to prevent the passage of the blood through it; and, again, it is known that arteries of considerable size, which are divided in operations, frequently contract so much that they cease to bleed, and their orifices, which were apparent immediately after the division, escape observation.

An additional argument against the agency of the arteries in the circulation, has been drawn by many writers from the fact, that the arterial trunks are occasionally converted into mere osseous cylinders, without interrupting the free transmission of the blood. This objection has little force, because the ossification is confined to the larger vessels, which are not supposed to exert, under ordinary circumstances, a very active power; but, if such a morbid change occurred in the small arteries, there is no doubt that it would interfere with the nourishment of the parts which were thus supplied; indeed, ossification of the tibial trunks only, is liable to cause mortification of the toes, foot, and leg.

A careful consideration of the experiments and opinions of the physiologists who have investigated this subject, joined to the observations and experiments which I have myself had an opportunity of making, have convinced me that the arteries exert an active contractile power, which assists very essentially in the circulation of the blood. This force, which has a great resemblance to muscular contractility, appears to have the same relation to the nervous system as the power of the heart; being, under ordinary circumstances, independent of the nervous power, but yet susceptible of being influenced by agents applied to the brain or spinal cord.*

The arteries are generally supposed to possess no sensibility in their healthy state, as they may be irritated in living animals by the scalpel, by the application of acids, &c., without producing any symptoms of pain. I believe, however, that the common opinion as to the insensibility of the blood-vessels is altogether unfounded. This mistake has arisen in the present, and in many other instances, from the erroneous idea, that parts which cause no pain on being irritated by mechanical or chemical agents, are insensible. But it is known that several structures, which excite no sensation when touched, are yet exquisitely susceptible to the impression of their proper stimulants; thus the retina, which may be pricked with the cataract needle without the consciousness of the individual, is capable of being vividly impressed by the rays of light.* I conclude then that the arteries, and particularly their internal coat, are endowed with a peculiar sensibility, which is fitted to receive the impression of the blood, and that this fluid acts as the appropriate stimulus to the contractility of the fibrous tunic. The importance of this property in a pathological point of view, is illustrated by the interesting experiments that have been lately performed by Mr. Morgan and Dr. Addison, concerning the influence of poisons on the animal economy. These gentlemen appear to have determined the long disputed question, as to the *modus operandi* of these deleterious agents, by ascertaining that the noxious effects of poisonous substances, introduced into the current of the circulation, *do not result from their direct application to the brain itself, but from the impression made upon the sensible structure of the blood-vessels, acting upon the brain, through the medium of the nervous system.*†

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* Philip, Exper. Inq. into the Laws of the Vital Functions, p. 84.

An important phenomenon is connected with the arterial circulation, which is called the *pulse*. We may define this to be the stroke which is felt by applying the finger to any artery of considerable size, with sufficient force to impede the flow of the blood. The cause of the pulse, which is a subject of the greatest interest to the physiologist and pathologist, has been variously explained. According to the most commonly received opinion, this phenomenon depends on the alternate dilatation and contraction of the artery, corresponding with the systole and diastole of the ventricle. Bichat, on the contrary, attributed the pulse to the locomotion or change of place, which occurs in the whole artery during the systole of the ventricle. It has also been supposed to result from the elongation which the artery experiences, when the heart forces into it a fresh portion of blood. And, lastly, some writers have thought that the pulse is produced by several of these causes united.

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* It is surprising how such an acute and admirable physiologist as Magendie, should have fallen into the error I have noticed above; such, however, is the fact, and, in consequence of it, he is led into a contradiction concerning the retina: for, after stating that the central part of that membrane is more sensible than the rest of its extent, he goes on to assert that the sensibility of the retina may fairly be called in question. See Compend. of Phy. p. 47.

† See Essay on the Operat. of Poisonous Agents upon the Living Body, p. 60.

We are indebted to Dr. Parry, whose inquiries were pursued with great accuracy and ability, for pointing out the real cause of the arterial pulse. He ascertained, by repeated experiments, that when a large artery is exposed in a living animal, not the least dilatation or contraction occurred during the systole and diastole of the left ventricle. He also found, that although a longitudinal movement may be perceived under certain conditions in the artery, it is by no means constant, and is not connected with the production of the pulse. The conclusion at which this excellent physiologist arrived, is, that "the chief cause of the pulse is a strong and predominant impulse of distention from the systole of the left ventricle, given by the blood as it passes through any portion of an artery forcibly contracted within its natural diameter."* But it is necessary to

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* Caleb H. Parry, Exper. Inq. into the Nature, Cause, and Varieties of the Arterial Pulse, p. 125.

It is proper to state, that Dr. Hastings has frequently seen the arteries conobserve that although this phenomenon is produced by the systole of the heart, yet that the arteries themselves have an important influence in modifying its characters; so that the pulse is not only an index, by which the state of the active powers of the heart can be ascertained, but it is also a certain guide to the condition of the arterial system.*

The use of the arteries is to convey the blood which they receive from the ventricles to all parts of the body. We learn from the preceding observations that these vessels are not passive tubes, but that they are endowed with an active power of contraction, and are at the same time highly elastic. The arteries are constantly full, their capacity varying according to the quantity of fluid they contain; this power of adaptation probably depends upon the tonic contraction of the fibrous coat, a property which is analogous with the tonicity of the muscles. Many facts might be mentioned in illustration of this important faculty, but I must confine myself to the following instances: after a large venesection, the artery, containing a diminished quantity of blood, contracts upon it, and in this manner the pulse becomes smaller. Again, when a ligature is applied around a large trunk, the vessel below the thread receives but a small proportion of blood, in consequence of which the parietes contract, and at length close the tube. Lastly, the ductus arteriosus, after respiration has occurred, no longer receiving the blood it had previously conveyed,

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tract and dilate; but this does not invalidate Dr. Parry's conclusion, because the contraction and dilatation appear to have been produced by the application of chemical or mechanical stimuli. See Treatise on Inflam. of Mucous Mem. of the Lungs, p. 31.

* The reader will find some very instructive observations on the Properties of the Arteries, and on the Pulse, in the published Lectures of Dr. Clutterbuck, contained in the "Lancet."

contracts on itself, and is gradually obliterated. This tonic contraction of the arteries not only adapts them to the quantity of fluid which they contain, but it also resists their distention during the systole of the ventricle; so that when the heart propels a fresh portion of blood into the aorta, the *vis à tergo*, instead of producing an enlargement of the calibre of the artery, is expended in forcing the fluid onwards. In addition to the tonic contraction, the arteries exert a propulsive action which very powerfully assists in the circulation, particularly in the small vessels.

The phenomena connected with the actions of the capillary vessels, will be alluded to in a subsequent part of this chapter.

PART THIRD.

SECTION I.

OF THE VEINS.

THE veins are the flexible canals which return the blood from all parts of the body to the heart.

The venous system is, like the arterial, double: one portion belonging to the general or systemic circulation, conveys the dark blood to the right auricle; the other division returns the florid blood from the lungs to the left auricle. There is also a distinct set of veins which form an appendage to the liver, consisting of the vena portæ and its branches.

The disposition of the venous system is arborescent, consisting of trunks and branches; but it is important to state, that when it is regarded according to the current of the blood, the arrangement is immediately opposed to that of the arteries. In consequence of this circumstance, most anatomists, acting on a physiological principle, trace the veins from their origin to their termination, or from the branches to the trunks; some however, assimilating the course of the veins to that of the arteries, follow them from trunk to branch.

The general veins of the body commence by minute radicles from the ultimate termination of the aortic system. The mode of origin, which will be considered when the capillary vessels are described, exhibits several varieties in the different organs and tissues, which relate to the size of the primitive roots, to the kind of connexion existing between them and the terminal arteries, &c. The veins of the lungs begin in a similar manner, from the last ramifications of the pulmonary arteries.

The capacity of the venous system exceeds that of the arterial, in consequence of the number and size of the veins being greater than those of the arteries. Thus we may remark that the two venæ cavæ and the vena coronaria correspond with the single trunk of the aorta; and that there are four pulmonary veins, and only one corresponding artery. In most parts of the body each artery is accompanied by two veins; in some organs, however, as in the stomach, the intestines, the spleen, the kidneys, the testicles, &c., the two species of vessels are in equal number; and a similar arrangement is observed in some of the great trunks, as in the iliac and subclavian arteries and veins. In a few instances the veins are less numerous than the arteries they accompany; this disposition is exemplified in the penis, the clitoris, the umbilical cord, &c.; but in these rare cases the capacity of the veins makes up for their want of number. In addition to the deep-seated veins, there are others placed on the external surface of the body, which are in some parts very large and numerous, and do not possess any corresponding arteries.

The veins, taken collectively, are then much more capacious than the arteries, and consequently they contain a larger quantity of blood; but, as Bichat has shewn, it is impossible to calculate with precision the amount of this excess. According to Haller the size of the veins is at least double that of the arteries, and frequently it is triple, or even more. The difference, however, is not the same in all parts of the body; it is also liable to great variation during life, according to the age of the individual, the constitution, the state of health, &c.; and in the dead body, the kind of death has a powerful influence on the state of the veins, so that in some instances, as when life has been destroyed by suffocation or apoplexy, they are gorged and distended; whilst in others, they are empty and collapsed.

The disposition of the venous system bears a general resemblance to that of the arterial; but it is distinguished by the veins being arranged in a superficial and a deep set. The former are placed immediately under the skin, and are therefore called the subcutaneous veins; they freely anastomose and form a network, which in some parts, as in the fore arm, is very evident through the skin. The deep-seated veins generally accompany the arteries, to which they are often intimately joined by a common sheath of condensed cellular membrane; there are, however, exceptions to this arrangement, as, for example, in the liver, the brain, and the spinal cord, in which organs the two orders of vessels run apart from each other. In those internal parts of the body where the veins cross the arteries, they are usually placed more externally than the latter; thus the subclavian veins lie before their arteries, the left renal vein before the aorta, the inferior cava before the right renal artery, &c.; but the relative situation is sometimes reversed, as in the instance of the iliac veins crossing beneath their arteries.

The branches of the veins are in the aggregate much larger than the trunks, from which it results that the blood, moving in a space which successively decreases, must circulate with greater velocity in proportion as it approaches the heart.

Having in the former part of this chapter described rather minutely the anastomosis of the vessels, I shall only add in this place, that the veins are characterized by the freedom of their communications, which are established not only by small branches, as in the arterial system, but very frequently by large trunks. They are also distinguished in some parts of the body, by forming intricate plexuses; these are met with on the surface of the body, and in a few of the internal organs, as in the spermatic cord, in the broad ligaments of the uterus, around the neck of the bladder, &c. The free anastomosis which exists between the veins, is a wise provision of nature to guard against any interruption in the return of the blood to the heart, which might otherwise have happened in consequence of these flexible tubes being very liable to compression.

Before considering the structure of the veins, I shall briefly allude to the peculiar system which is formed by the vessels of the abdominal viscera. The vena portæ, which consists of a central trunk, and two sets of branches, is distinct both from the arterial and venous systems, being placed between the terminations of the stomachic, intestinal, and splenic arteries, from which it arises, and the radicles of the hepatic veins, in which it ends. This vessel is equally peculiar with respect to its functions; for on the one hand, it acts as a vein by returning the blood from the viscera; whilst on the other, it performs the office of an artery by secreting the bile. The vena portæ is, however, more allied to the veins than to the arteries, in consequence of its structure and of the kind of blood that it contains.

SECTION II.

ORGANIZATION OF THE VEINS.

THE coats of these vessels are much thinner than those of the arteries, and they also present other peculiarities which require to be noticed.

The *internal* membrane lines all the veins with the exception of the pulmonary; it also covers the inner surface of the right cavities of the heart and of the pulmonary arteries. Many anatomists suppose that the sinuses of the dura mater do not possess a lining membrane; but the fallacy of this opinion can be shewn by a careful dissection of these vessels. This tunic is more thin and delicate than the inner coat of the arteries, and it is also more extensible and less brittle.

The internal membrane forms within most of the veins, numerous folds or valves, which contain condensed cellular substance, and occasionally distinct fibres. Each of these folds has an adherent margin, which is firmly attached to the circumference of the vessel; and a free edge, which is straight or slightly concave, and turned in the direction of the heart; both these borders are rather thicker than the other part of the valve. When the valve is put in action by the pressure of the blood, the surface towards the heart becomes concave, and the other side convex; it may also be noticed at this time, that the vein, which is rather dilated opposite to the valve, is rendered turgid and somewhat prominent.* In most of the vessels the valves are placed in pairs; in the vessels whose diameter is less than a line, the valves are single, and a similar disposition exists at the termination of the vena coronaria; some of the large trunks possess triple valves; and in some rare instances the folds are quadruple, and even quintuple.

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* The irregular or knotted appearance seen in the injected veins, is owing to the above dilatations, which are similar to the sinuses of the aorta, or of the pulmonary artery.

The number of valves is subject to variation in the different regions of the body; but it is generally in an inverse ratio to the size of vessels, although in the very small veins they entirely disappear. In the superficial vessels, in those exposed to the compression of the muscles, in the veins of the lower extremity, the valves are numerous; they are also usually observed in the places where the branches empty themselves into the trunks. On the contrary, they are not found in the system of the vena portæ, in the veins of the uterus, of the heart, of the lungs, of the brain, or of the spinal cord; they are also absent in the venæ cavæ, in the umbilical vein, and, usually, in the renal veins; the vena azygos seldom possesses any valves.

The mechanism of these valvular bodies, which is so simple and yet so admirably adapted to its purpose, is such that, although it allows the free passage of the blood towards the heart, it effectively prevents any reflux in the opposite direction, and in this manner it powerfully assists in the venous circulation.

The *middle membrane* is much thinner than the corresponding structure of the arterial system; it is formed of reddish, soft, and yielding fibres, which may be observed in the larger veins running longitudinally. It is denied by Bichat and Meckel, that there are any transverse fibres, and it is true that none can be satisfactorily demonstrated passing in that direction. This coat is proportionally thicker in the small than in the large veins; it is also more developed in the system of the ascending cava, than it is in that of the descending; and, lastly, the veins on the superficial parts of the body are more distinctly fibrous than those which are deep-seated. These facts, as Hunter remarked, shew that the contractile power is increased wherever there are obstacles to the return of the blood. A layer of fibres resembling those of the auricle, may generally be seen in the two venæ cavæ for about an inch before they terminate. The middle coat is deficient in the sinuses of the cranium, in which vessels its place is supplied by the dura mater.

The external membrane is composed like the same tunic of the arteries, of elastic cellular substance; it is not, however, so thick nor so much condensed. It is very firmly connected with the middle and internal coats by means of fibrous processes.

The veins are supplied with vasa vasorum, and also with nerves, which may be traced in some of the large trunks.

SECTION III.

PROPERTIES AND USES.

IT has been generally admitted since the experiments of Wintringham, that the density of the veins exceeds that of the arteries; but there is great reason to doubt the correctness of this opinion, which is opposed to the observations of several excellent modern anatomists. The strength of the venous parietes is also stated to surpass that of the arterial; and, if the inquiries of Wintringham be considered conclusive, the truth of this statement must be allowed. My own experience, however, induces me to agree with Dr. Gordon in thinking, that the veins are much weaker than the arteries.

The veins are capable of being considerably extended, particularly in the circular direction, without rupturing; this property is displayed in the great dilatation which the vessels undergo when the return of the blood is obstructed; also in cases of aneurismal varix, and in forcible injection after death. The parietes of the venous tubes are very elastic, but less so, according to the best modern writers, than the arteries; it was, however, contended by Haller and Bichat, that the former vessels possess more elasticity in the transverse direction than the latter.

It is generally supposed, that the veins are not endowed with an active power of contraction, or, as it is more usually called, with irritability; but many facts may be mentioned which prove the existence of such a property. It is admitted by Haller, and most other physiologists, that the trunks placed near the heart possess irritability; and the direct experiments of Verschuir and Hastings shew that this power extends to the whole venous system. Again, if a vein in a living animal be tied with two ligatures, and is then punctured between them, the blood is rapidly ejected; whilst, if the same experiment be performed after death, the blood oozes out slowly and imperfectly. Although the contractile power of these vessels seems to be well established, it is necessary to add that it is inconsiderable and not to be compared to that of the arteries.

The remarks which were offered at page 279, concerning the sensibility of the vessels in general, may be applied to the veins.

There has been much discussion amongst physiologists concerning the powers which accomplish the venous circulation. The illustrious Harvey supposed that the propulsive action of the heart, extending its influence through the arteries and capillaries to the veins, was the efficient cause of this process. It has been determined, however, by subsequent investigations, that the arterial and capillary vessels themselves, exert an important influence on the movement of the blood. Bichat, indeed, thought that the venous circulation depended solely on the action of the capillary system ; but it is easy to disprove this hypothesis by direct observation. I shall satisfy myself with mentioning two facts, to shew that the systole of the left ventricle has a decided influence on the flow of the blood within the veins. The most striking illustration is afforded by the experiment of M. Magendie, who passed a ligature around the thigh of a dog, so as to include every part of it, except the femoral artery and vein. He tied the latter vessel, and then made a small opening in it, and having done so, he found that the blood immediately escaped, and formed a considerable jet; but that, on compressing the artery, the flow soon stopped, although the whole length of the vein was full ; on removing the pressure from the artery the stream from the vein was re-established. The second instance which I shall adduce to demonstrate the influence of the heart, is the distinct pulsation that is occasionally perceptible in the veins, and which is synchronous with the stroke of the left ventricle. We may then conclude that the *vis à tergo* which propels the blood along the veins, is derived principally from the heart, and from the contraction of the arteries and capillaries.

Physiologists have enumerated some other causes, which have been thought to assist in the venous circulation, such as the contraction of the veins themselves; the pulsation of the neighbouring arteries; the compression of the surrounding parts, particularly of the muscles; and, in a more especial manner, atmospheric pressure. The facts which I stated when describing the structure and properties of the veins, render it evident that these vessels possess an active contractile power, which assists in propelling their contents.

With respect to ths pulsation of the arteries, it is very doubtful if it has any influence on the venous circulation. This opinion, which is supported by so many high authorities, was founded on the erroneous idea that the arteries alternately dilated and contracted; but, as it is now admitted, that there is no perceptible motion in the artery during the ordinary action of the heart, it is difficult to conceive how any power of the above nature can exist. The pressure of the muscles and of the skin, appears to favour the return of the venous fluid; and it is well known to surgeons, that artificial compression, when properly applied, is a most powerful means of removing congestion of different parts by aiding the powers of the circulating vessels.

The most important auxiliary to the *vis à tergo* is, according to a commonly received opinion, the pressure exerted by the atmosphere on the surface of the body. Various attempts have been made to explain the mode in which this pressure acts on the veins. Some physiologists contend that a tendency to a vacuum is produced, in consequence of the active dilatation of the cavities of the heart; others think that the elasticity of the lungs powerfully assists in dilating the chambers of the heart;

and, lastly, it has been supposed that, as in the act of inspiration the expanding parietes of the chest tend to leave a vacuum, the pressure of the atmosphere must necessarily force the blood into the thorax.

In the ordinary and quiet state of the circulation, I believe that the influence of inspiration in determining the flow of the venous blood, is very inconsiderable; but when the breathing is excited by any cause, the contents of the veins are forcibly drawn towards the heart during inspiration. With respect to the dilatation of the cavities of the heart, it appears that the auricle during its diastole spontaneously expands, and it is probable that the mechanism of the chest also assists in separating the walls of the auricle. I conceive, however, that the effect of the thoracic vacuum, whether it occurs in the lungs or in the heart, is not indispensably essential to the venous circulation. This opinion is supported by the fact, that if the vena cava, or any other great vein, is tied so as to cut off the communication with the heart and thorax, it is distended with blood coming up towards the heart; and if wounded on the distal side of the ligature, the blood streams out till death ensues. Again, in the numerous animals which have neither heart nor lungs, and in the imperfect human fœtus, the heart is wanting; it is evident in these cases that no tendency to a thoracic vacuum can take place, and yet the circulation of the venous blood is perfectly accomplished. The instance of the circulation in the system of the vena portæ, might be adduced as an additional proof, that the occurrence of the above phenomenon is not necessarily required.

The blood moves more slowly in the veins than it does in the arteries, partly in consequence of the much larger capacity of the venous system, and partly owing to the decline of the propulsive powers. But the current in the veins is more rapid than it is in the capillaries, because as these small vessels unite to form the veins, the capacity of the vascular channel diminishes; and for the same reason, the blood flows with greater velocity as it passes from the branches towards the trunks of the venæ cavæ.

The contraction of the ventricle, which causes the blood in the arteries to flow *per saltum*, does not produce a similar effect in the veins, so that if one of the latter vessels is opened, the stream that issues from it is perfectly uniform. It occasionally happens, however, when the action of the heart is violently increased, or when there is some obstacle in the circulation, that a distinct pulsation is observed in the veins, which is synchronous with and dependent on the stroke of the ventricle. There is also another kind of venous pulse in the vessels placed near the heart, which is produced by a very different cause, viz. the contraction of the auricle. It has long been remarked, that when this cavity contracts, a certain quantity of the blood which it contains, flows back into the venæ cavæ; and in some cases, this undulation extending to the iliac and jugular veins, may be seen in the latter vessels, particularly in a thin individual. The distention thus produced, must be distinguished from the fulness that is caused by the act of expiration, during which period, the blood being forced from the chest towards the veins, is accumulated about the head and neck, and also in the viscera of the abdomen. It is evident from the mechanism of the venous system, that the reflux cannot in either case extend beyond the first pair of valves.

PART FOURTH.

SECTION I.

OF THE CAPILLARY VESSELS.

THE minute tubes which constitute the ultimate terminations of the arteries and the first origins of the veins, are distinguished by the name of *vasa capillaria.* Bichat regards them as forming a system by themselves, which is distinct from the rest of the vascular system, and in which the vital functions of secretion, nutrition, calorification, &c. are accomplished. Although this celebrated physiologist made too defined a separation between the capillaries and the larger blood-vessels, yet it is certain that these small canals are the mechanical agents, by which the various changes that occur in the composition of the body, whether healthy or morbid, are effected.

The capillary vessels are so minute that they escape detection by the naked eye. This circumstance gave rise to many errors before the art of magnifying objects with optical instruments, and that of filling the vessels with fine injection, were discovered. Thus anatomists for a long time believed, and the opinion is supported by some in the present day, that a peculiar substance or parenchyma intervened between the smallest visible branches of the arteries and the commencement of the veins. The truth of this theory is disproved by the fact, that a coloured fluid may be thrown from the arteries into the veins without any extravasation between them. A more direct source of information is obtained by carefully examining with a microscope the circulation in the transparent parts of animals, as the web of the frog's foot, or the mesentery of the rabbit. By this means we are able to trace the ramifications of the arteries till they become directly continuous with the branches of the veins.

It is impossible to state with precision where the capillaries begin, or where they end. It will, however, be sufficient for all useful purposes, if we include under this denomination all arteries and veins which are invisible to the naked eye. I am aware that this definition is not free from objection, because, in the first place, it is arbitrary, for vessels which are seen by one individual may be imperceptible to another whose vision is less powerful; and in the second place, many writers restrict the term of capillaries to the minute ramifications of the arterial system.

The circulation of the blood being double in the human species, it follows that the capillary system must likewise be divided into two parts. One set of capillaries is diffused in all parts of the body, being placed between the terminal branches of the arteries and the roots of the veins; the other set, less extensive and capacious, is situated between the minute ramifications of the pulmonary arteries and the origins of the pulmonary veins. In the former class the arterial blood is converted into venous; and in the latter, the venous blood is changed into arterial. The capillary vessels which are placed at the commencement and termination of the vena portæ, form a part of the general capillary system.

The capillary vessels are not all of the same size;

those which proceed from the arteries become smaller till at length they only receive one red particle at a time; from this point they begin to enlarge, and continue to do so till they terminate in the primitive branches of the veins. It is a question of interest to know, if there are any capillaries so small that they cannot admit the coloured part of the blood. The great majority of anatomists think that such vessels do exist; indeed it is surprising that any doubts should have arisen on this subject, at least in modern times. Many parts of the body, such as the cartilages and the diaphanous membranes of the eye, are supplied by vessels which carry only the colourless portion of the blood, and which therefore escape observation; but we cannot for this reason suppose that these parts have no arteries or veins. The contrary is proved in inflammation, in which state many of the transparent vessels become apparent, in consequence of being preternaturally dilated. Thus in ophthalmia, the minute arteries of the conjunctiva appear distinct, because they are distended with red blood; and even the vascularity of the cornea is demonstrated by continued inflammation. It is impossible to suppose that in these and similar instances, the vessels which are seen, are generated by the diseased action, and that they did not previously exist.

Although the existence of these colourless vessels appears to be satisfactorily proved, yet it must be confessed that little is known of their real nature. Haller, Bichat, and others, have stated that in many parts of the body, as the skin, the serous and mucous membranes, &c., the arteries terminate in exhaling tubes, which are themselves supposed to end by little orifices or mouths; and in other organs, the pellucid capillaries are said to be continuous with excretory ducts. Other anatomists, as Mascagni and Richerand, contend, on the contrary, that the capillary vessels neither end in exhalants nor are continuous with excretory ducts; but that they possess lateral and organic pores, through which the various substances necessary for nutrition and secretion, are separated from the blood. It is evident that both these theories are entirely conjectural, for it is impossible to perceive either exhalant orifices or lateral pores.

The experiments of M. Fodéra upon the imbibing powers of the living solids, have induced M. Magendie to revive the old opinion, according to which exhalation depends on transudation. These investigations certainly shew that the tissues of a living animal are capable of being penetrated by substances which are in contact with them.* But this is only one step towards elucidating the wonderful and ever-varying process of secretion, by which the most dissimilar fluids are separated from the common mass of the blood. Notwithstanding the great progress that has been made in the study of the animal economy, and the perfection which has been attained in the construction of the microscope, I believe we are still ignorant of the connexion which exists between the small blood-vessels and the solids of the body; or, in other words, of the process by which the particles required for nutrition, and those which form the secretions are separated from the circulating blood.

It has been stated in a preceding page, that the microscope demonstrates an immediate communication between the arteries and veins; but these anastomoses are so multiplied and intricate, that it is very difficult to convey by words an idea of the beautiful appearance which is presented to the eye of the observer. In some places the direction of one of the smallest arteries being altered, it is reflected on itself, and thus becomes an incipient vein; in other places small branches are sent off from an artery into a parallel vein; lastly, it often happens that several minute arterial ramifications are continuous with a single vein. The small venous radicles which spring from the capillary tubes, are generally larger and more numerous than the arteries; they also more freely communicate with each other, and with the capillaries. The anastomoses are established by vessels that are invisible to the naked eye, but which may be distinctly seen in the web of the frog's foot, when a good microscope is employed.

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* M. Fodéra injected a poisonous substance into a portion of an artery which was included between two ligatures, and carefully detached from all the surrounding parts. In a short time the poison was imbibed by the parietes of the vessel, spread itself on the outside, and very soon destroyed the animal.

No direct connexion between the arteries and lymphatics can be perceived, even with the aid of magnifying glasses, and in consequence of this circumstance most anatomists deny that it exists. It is, however, found that injections pass from the arteries into the lymphatics; and therefore Magendie, adopting the ideas of Bartholine and others, considers that the latter have an immediate communication with the former.

The number of the capillaries, and their proportion with the solid substance, are extremely various in the different organic structures. In many parts, as the epidermis, the arachnoid, and the cellular membrane, no arteries can be injected; but this depends on the imperfection of the method employed, and not on an actual deficiency of blood-vessels. The cartilages in the fœtus can be injected, but not in the adult. The serous membranes are made rather red by the injection of their vessels. The fibrous structures receive many capillary arteries, some of which admit the coloured part of the blood; the bones are more vascular, and are readily injected. The muscular and nervous systems are abundantly supplied with capillaries; but the most vascular parts of the body are the secretory organs, the skin, the mucous membranes, and the lungs.

The organization of the capillary vessels cannot be ascertained by examination, in consequence of the minuteness of these tubes, and the difficulty of distinguishing them from the parts by which they are surrounded. We may, however, conclude that they are lined by the continuation of the internal membrane of the arteries; and it is also probable, as they exhibit distinct marks of contractility, that they are provided with a fibrous coat.

SECTION II.

PROPERTIES AND FUNCTIONS.

THE actions of the capillary vessels are essential to the production of most of those operations, which are required for the support of life. The opinions of physiologists are, in the present day, divided as to the existence of an active contractile power in these small blood-vessels; and when the great importance of the question is considered, we cannot be surprised at the number of writers who have engaged in the controversy. According to some authorities, the capillaries are merely passive tubes, which are not provided with irritability.[*] Others, on the contrary, contend that they have a contractile power, which enables them to carry on the circulation quite independently of the heart; this power was called by Bichat, insensible organic contractility. Lastly, many excellent physiologists suppose, that the capillary circulation is influenced by the action of the heart; but that the small vessels have themselves an active force, which enables them to assist in propelling their contents, and which may be exercised independently of the heart. As it would be difficult to reduce within the limits of this work, the numerous considerations that are connected with this most comprehensive subject, I shall confine myself to pointing out some facts which appear to prove the correctness of the last opinion.

It has been already shewn that the propulsive power of the ventricle extends to the venous system;[†] now, as it is evident that that power must have previously acted on the capillaries, I conceive the first part of the position must be admitted, viz. that the capillary circulation is influenced by the action of the heart.

The second part of this opinion may be substantiated by observing certain phenomena which occur in the human body, and by the results of experiments performed on the lower animals. It is well known that local action frequently takes place, by which blood, and other fluids, are determined towards individual parts of the body, without the heart's action or the general circulation being in the least affected. Mental emotion is often the exciting cause of the great local accumulation. Thus, shame causes blushing; voluptuous ideas produce erection; and the sight of food excites, in a hungry person, a flow of saliva. At other times local action may be produced by mechanical irritation; for example, titillation causes erection of the nipple, a particle of iron renders the vessels of the conjunctiva turgid, &c. Again, in local inflammation, the activity of the small arteries is increased, although the condition of the heart is not affected. It has, indeed, been implied, by an author of great excellence,* that, in similar instances to those above mentioned, a prior action occurs in the heart, which is the occasion of the local distention. But, if this supposition were founded in truth, which there is great reason to think it is not, it would not explain the phenomena which are observed. Such an increase in the power of the heart would certainly accelerate the general circulation; but we cannot conceive how it could influence the flow of blood in any particular set of vessels, unless those vessels had themselves a local source of action.

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[*] This word, which was first employed by Glisson, has, since the time of Haller, been generally used by physiologists, to express the vital property which enables certain parts of the animal body to contract or shorten their fibres upon the application of a stimulus.

[†] See p. 292.

The important experiments which have been performed by Dr. W. Philip, Dr. Thompson and Dr. Hastings, shew, in a still more striking manner, the contractile power of the capillaries. Thus the circulation continues in them, after a ligature has been tightly bound around the leg of a frog—after the great vessels of the heart have been all tied—nay, more, after the heart has itself been removed, or has long ceased to act.†

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* Dr. Charles Parry, Addition. Expts. on the Arteries, p. 109.

† Dr. Philip has seen the circulation continue in the mesentery of the rabbit for an hour and a quarter after the excision of the heart. Exper. Inq. into the Laws of the Vital Functions, 3d edit. p. 178. I have myself frequently

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SECTION III.

OF THE ERECTILE TISSUE.

IN certain parts of the body, the small arteries and veins have a peculiar disposition which causes them to be very greatly distended with blood, at any time when their action is excited; this arrangement of the vessels gives rise to what has been termed the *erectile tissue.*

It is observed in several places, but it is most distinct in the organs of generation, as in the penis, the clitoris, the nymphæ, and the nipple of the breast; it is also evident in the papillæ of the skin and mucous membranes, and, according to some writers, in the spleen.

The opinions of anatomists have, for a long time, been divided concerning the character of the erectile tissue. The majority state that in the penis, in which organ it has been principally examined, it is composed of spongy and loose cellular substance, interposed between the termination of the arteries and the commencement of the veins. But many excellent anatomists, amongst whom may be mentioned Hunter, Cuvier,

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* The reader may consult with great advantage the work of Dr. Bostock, for a comprehensive account of the influence of physical and vital agents in the production of secretion, nutrition, respiration, &c.

The contractility of the capillary vessels may also be excited by the direct application of stimulants, without the action of the neighbouring arteries being at all influenced.

The conclusion to which the preceding facts lead, is, that the small blood-vessels are provided with an active and independent power, which materially assists the heart in propelling the blood onwards to the veins.

The functions of the capillaries are much more important than those which are exercised in the other parts of the vascular system. The arteries and the veins are, in fact, entirely subservient to the action of these vessels; the former, by bringing the fluid material, the blood, which is destined to fulfil certain uses, and to undergo certain changes, as it traverses the capillary system; the latter, by returning the altered blood after the necessary processes have been accomplished. The general capillaries, or those placed between the termination of the aortic arteries and the origin of the common veins, are the agents which effect the vital functions of secretion and nutrition, in the completion of which, the blood experiences such changes, that it becomes deteriorated and unfitted for the purposes of the economy. The capillaries of the lungs are connected with equally important processes, for, in these vessels, the blood is renovated by being freed from the noxious principles it had acquired in the general circulation; and in the same tubes, the chyle and the lymph are assimilated with the nutritious fluid.

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observed the circulation going on in the same part, upwards of an hour after the action of the heart had ceased. In performing these experiments, it is, however, necessary to distinguish between the motion of the blood, which depends on the action of the vessels, and that which is often produced by accidental causes.

It is very difficult, or, more correctly speaking, impossible, in the present state of our knowledge, to decide on the real nature of the phenomena which occur in the capillary vessels. They appear, however, to be of a mixed character, and to depend on the conjoined operation of mechanical, chemical, and vital actions.*

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Tiedemann, and Beclard, have demonstrated that the erectile structure is produced merely by a particular arrangement of the small sanguineous vessels, and especially of the veins.

This tissue can be distinguished in the penis of the human subject; but it is more apparent in the larger animals, such as the horse or elephant. The intimate structure of the corpus cavernosum may be thus described: externally it is surrounded by a fibrous and elastic sheath, which sends numerous processes to the interior, where they separate, and at the same time support, the vascular ramifications; the internal portion is made up of numerous arterial branches, which freely anastomose with each other, and also with the large roots of the deep vein. These communications are extremely large and frequent; and, it is also observed, that the venous branches, which present many dilatations, freely unite with each other. When one of the deep arteries of the penis is very successfully injected, the fluid first distends the ramifications of that artery; then the plexus, which is formed by the vein; and at length, having produced erection, it returns by the great dorsal vein; the same effect is more easily obtained by injecting from the vein. The erectile tissue of the corpus spongiosum is rather different from the preceding, in consequence of the existence of a remarkable network of veins, which surrounds the urethra, throughout its whole extent. In the membranous portion these veins are accumulated so as to form two columns, which leave a groove between them, extending from the caput gallinaginis to the glans penis. This curious structure, which was discovered by the late Mr. Shaw, must tend to contract the calibre of the urethra during erection; and, as the two venous columns are united together around the sinus pocularis of the prostate gland, it has been thought that, during coition, they may prevent the semen flowing back towards the bladder, or the urine forwards into the urethra.

The disposition of the vessels in the clitoris and nymphæ is the same as in the cavernous body of the penis.

The papillæ of the cutaneous organs are provided with the erectile tissue, although on account of their minuteness, it is difficult to detect it. The most favourable situation to examine it, is in the papillæ of the tongue. Each of those eminences receives, in addition to the nervous filaments, a great number of small blood-vessels, which are distinguished by their serpentine course, and by their very free communications with each other. In the state of inaction the papillæ are indistinct, soft, and pale; on the contrary, in the state of erection, they become enlarged, straightened, red, and highly sensible. The nipple, or papilla of the mammary gland, does not appear to differ from the preceding, except by its greater dimensions.

The erection of the various parts which are provided with this tissue, depends on the repletion of the blood-vessels, and particularly of the veins. This fulness is produced by the joint operation of two causes; the first is the increased activity of the small arteries, by which a larger quantity of blood is propelled into the veins; the second, is the stagnation which occurs in the venous branches, and their consequent dilatation. The erection of the penis in the male, and of the clitoris in the female, has been frequently attributed to the mechanical impediment which is offered to the return of the venous blood, by the contraction of the muscles. This opinion I believe to be ill-founded; for there is every reason to conclude that the erection of the above mentioned bodies, depends on the general excitement which is produced in the circulation of the organs of generation, by the venereal appetite.* It is probable, however, that when erection has taken place, the almost spasmodic action of the muscles of the perineum powerfully assists in prolonging that state, and in increasing its intensity.

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* It has been ascertained that the internal organs are distended with blood during the excited state of the sexual passions. Thus Cruikshank found the genitals of the female rabbit during heat, to be prodigiously turgid with blood; the vagina was of a purple colour, and the Fallopian tube, being greatly injected, was almost black. Are not these phenomena very analogous with the erection of the external organs?

PART FIFTH.

OF THE LYMPHATIC SYSTEM.

This system consists of a great number of delicate pellucid tubes, called lymphatic vessels, and of certain bodies placed in their course, which are distinguished by the name of lymphatic glands or ganglions.

Section I.

OF THE LYMPHATIC VESSELS.

The lymphatic vessels, which are also termed from their office *absorbents*, form an important part of the vascular system; they are more especially connected with the veins, of which, indeed, they may be considered as forming an appendage. These vessels, in consequence of their tenuity and of the transparency of the fluid they contain, are more difficult to perceive than the arteries or veins. This indistinctness was doubtless the cause of the lymphatics remaining during a long period unknown; so that their existence was only first satisfactorily ascertained about two hundred years ago, although it is certain that the ancients knew something of absorption, which they thought was accomplished by the veins and arteries. The important discovery of this system was commenced by Aselli, an Italian anatomist, who accidentally observed in a dog the lymphatics of the mesentery, which he named, on account of the white-coloured fluid they contained, *venæ lacteæ*. He not only discovered these vessels, but he also pointed out their use, by stating that they absorbed the chyle from the intestines. The lacteals were subsequently detected in the human body. The common lymphatics of the body were discovered some years afterwards by Rudbec, or, according to some authorities, by Joliffe or Bartholine. As these vessels contained a thin watery fluid, they were supposed to be different from the lacteal tubes; and to distinguish them, they were called *vasa aquosa*, *vasa lymphatica*, &c. This distinction between the lymphatic and lactiferous vessels, has been generally retained, and it is even adopted by most anatomists of the present day. There is, however, no sufficient reason to justify the division, for the lacteals are nothing more than the lymphatics of the intestines, which sometimes contain chyle, and at other times lymph.

The lymphatic vessels collectively possess an arborescent arrangement, but it is not so striking as in the other divisions of the vascular system. In the limbs and in the parietes of the trunk, they are distributed like the veins, in a superficial and deep-seated plane. The vessels which belong to the former class, are placed under the skin in company with the subcutaneous veins. The deep and larger lymphatics are lodged principally in the interstices of the muscles, where they surround the trunks and branches of the arteries. A similar disposition is also observed in the internal organs, as the lungs, stomach, liver, &c.; in these viscera, one set is situated immediately beneath the peritoneal coat, and the other more deeply on the mucous membrane.*

The principal lymphatic vessels generally observe a straight course; in the extremities, for example, they run in the form of long parallel tubes, which sometimes pass two or three feet, or even more, without presenting any ramifications. It has, however, been truly remarked by Cruikshank, that the absence of communications is in most instances only apparent, depending on the difficulty of injecting the branches in consequence of the number of their valves. In many parts of the body, as the stomach, intestines, &c., the lymphatics ramify in the manner of the arteries; and in other places, as on the surface of the liver, and still more distinctly on the lungs, they form a large network, the areolæ of which are filled up with finer and more intricate networks of smaller lymphatics.

These vessels anastomose with each other most freely, not merely by their small branches, but by trunks of large size, which frequently unite and separate again, so as to form in many places distinct plexuses. It is worthy of remark that when two of these vessels join, the tube which proceeds from them is seldom larger than either of them separately. Another peculiar fact connected with the anastomosis of the lymphatics, is that, after they have united to form a trunk, they again separate into branches, which ramify and subsequently end in other trunks; these alternate unions and divisions occur several times before the vessels ultimately terminate. The superficial absorbents are particularly distinguished by the freedom of their communication; it is indeed so great, that if all those vessels which are placed between the skin and the external aponeurosis, could be injected in one subject, the body would appear surrounded by a great lymphatic network.

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* The course and arrangement of the lymphatic vessels are very beautifully represented in Mascagni's splendid work, Vasor. Lymph. Corp. Hum. Hist. et Ichnographia.

The disposition of this system renders it impossible to make an accurate estimate of its total capacity. The difficulty arises from the circumstance of the lymphatic vessels being dispersed in an infinite number of branches, which bear no regular proportion to the size of the trunk in which they terminate; thus Mr. Cruikshank has mentioned several instances in which he found branches equal to, or even surpassing the thoracic duct in magnitude. Without, however, attempting any very exact calculation, it may be affirmed that the collective size of the lymphatics is about double that of the arteries.

For the reason just stated, the number of the lymphatic vessels is much greater than that of the arteries and veins. This excess is very striking in the superficial parts of the body, where from ten to twenty, or even thirty lymphatics may be counted accompanying one subcutaneous vein. There are at least two deep lymphatics with each artery, and frequently there are four, six, or more.

The number of these tubes is subject to considerable variation in the different organs. They are extremely numerous in the skin, and in the mucous membranes, especially of the small intestines, where they are termed lacteals; also in the testicle, liver, spleen, lungs, &c. Their number is less in the serous membranes, in the muscles, and bones; and there are yet fewer in cartilage, ligament, and tendon. In certain parts of the body, although the most careful investigations have been made, no lymphatics have been satisfactorily discovered. They have not been traced in the globe of the eye, in the substance of the brain or spinal cord; a few are represented in the plates of Mascagni, on the dura mater, and also on the pia mater. It is also generally admitted that the placenta is not provided with lymphatics.

SECTION II.

OF THE ORIGIN AND TERMINATION OF THE LYMPHATIC VESSELS.

THESE vessels are so extremely minute at their commencement, that it is impossible to state any thing with certainty respecting the manner in which they actually arise. It was formerly thought that the absorbents, like the veins, were directly continued from small arteries, which were therefore called lymphatic arteries. This hypothesis was supported by the fact, that fluids thrown into the arteries readily pass into the lymphatics. It has, however, been objected to this statement, that the injected fluids do not reach the lymphatics immediately from the arteries; but that they are either extravasated into the cellular membrane, and thence absorbed, or that they enter the lymphatic tubes by transudation. The majority of anatomists, since the time of Drs. Hunter and Monro, believe that the absorbing vessels begin by open mouths or orifices, which are placed on the surfaces of the different membranes, and in the substance of the various organs. This theory is rendered probable by the observations of Cruikshank, who saw on the villi of the small intestines, with the aid of the microscope, some hundreds of little openings, which were the origins of lacteal vessels. It is true that neither Cruikshank nor any of his successors, have been able to perceive the orifices of the common lymphatics; but as the lacteals are merely the absorbents of the intestines, it has been contended that what is proved with respect to them, must be admitted of the other parts of the system. The evidence which has been brought forward on both sides of this question, is so forcible and at the same time so contradictory, that it is impossible to form a satisfactory conclusion; and therefore I believe that the minute origin of the lymphatics is one amongst the many points of minute anatomy, which yet remain to be discovered.

The absorbent vessels, as soon as they are sufficiently large to be perceived, are observed to communicate with each other in the manner already described; and subsequently, after a longer or shorter course, they appear to terminate in the lymphatic glands. Minute inspection shews that they do not end in these bodies; but that, having ramified within them, they are still continued onwards, and either pass to other glands, or to the trunks which are supposed to form the common termination of the lymphatic system. The principal trunk is called the *thoracic duct*, which receives the absorbents from the lower half of the body, the interior of the chest, the left upper extremity, and the left side of the head and neck. This canal begins opposite to the third or second vertebra of the loins; it passes upwards on the spine till it reaches the superior part of the chest; it then crosses obliquely to the left side, and eventually empties itself into the angle formed by the union of the left internal jugular and the left subclavian veins. There is considerable irregularity in the thoracic duct; it often divides into two or more large branches, whilst it is placed in the posterior mediastinum, and I have sometimes seen it form a very intricate plexus of small tubes. The remaining lymphatics end in a smaller trunk on the right side of the body, which corresponds in its termination to the thoracic duct. It generally happens that there are on each side two or three lesser lymphatics, which open into the jugular and subclavian veins.

The communications between the lymphatic and venous trunks, which I have just described, were generally supposed, until late years, to be the only connexions existing between the two systems. The recent investigations of several anatomists have, however, proved that the absorbents communicate with the veins in many other situations.* It has, for example, been observed by Fohmann, that many of the lacteal vessels end in the veins of the viscera; and Lippi has shewn, that the absorbents of the abdomen open freely into the neighbouring venous trunks and branches. According to a late writer,† the lymphatics terminate in three different modes:—1. They empty themselves, whilst in the very substance of the different organs, and still being of a capillary size, into the venous branches. 2. They end in the small veins within the lymphatic glands. 3. They open by great trunks into the large veins of the neck. These intimate connexions will explain, as we shall find hereafter, the cause of many of the discrepancies which have occurred in the experiments on lymphatic and venous absorption.

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* It is proper to state, that Mr. Bracey Clarke discovered, some years ago, communications between the thoracic duct and the lumbar veins in the horse. —*Rees's Cyclopædia*, article *Anatomy, Veterinary*.

† Lauth, Essai sur les Vaisseaux Lymph. *Strasbourg*, 1824.

SECTION III.

ORGANIZATION OF THE LYMPHATICS.

THE parietes of the lymphatic tubes are so thin, that their composition is ascertained with difficulty.

The internal membrane, which, according to many authorities, is the only coat possessed by these vessels, is very thin, dense, and transparent. It is distinguished by forming an immense number of valves, which are more numerous and thinner than the same folds of the veins; but in proportion to their thickness they have an equal or even a superior degree of strength. The disposition and form of the lymphatic valves are very similar to those of the venous system; they are semicircular or parabolic in form, and each has its convex edge attached to the side of the vessel, and its straight margin loose in the interior. They are usually placed in pairs; but sometimes, especially where the branches terminate in the trunks or in the veins, there is only a single circular valve, which frequently closes the canal in an imperfect manner. The number of the valves, which is extremely irregular, is greater in the small lymphatics than it is in those of larger calibre. In the vessels of a medium size, they are found at intervals of $\frac{1}{8}$ or $\frac{1}{16}$ of an inch; in the spermatic absorbents, for example, the valves are regularly disposed about a line asunder. On the contrary, in some places a lymphatic is seen to run several inches without a single valve; this is particularly remarked in the thoracic duct, which has, in many bodies, only three or four pairs of valves, although in other instances it is crowded with them. The terminations of the great trunks in the subclavian veins, are provided with double valves, which effectually prevent the reflux of the venous blood into their cavities. In consequence of the great number of valves, and the dilatations which occur between them, the vessels present a jointed appearance when they are injected.

The second, or external coat, can be demonstrated in the thoracic duct of horses; and Cruikshank affirms, that he has seen fibres in the duct of the human subject.* The phenomena which are displayed by the absorbent vessels, seem to prove that they possess a structure which is capable of contraction; but it must be acknowledged that no fibrous coat can be detected.† The outer surface of these vessels is covered with a loose cellular tissue, by which they are connected with the surrounding parts; this substance has been considered by some anatomists as forming the external coat.

It has been ascertained by delicate injections, that the lymphatics are furnished with nutrient blood-vessels; and it is also thought that their walls receive minute absorbents. No nerves have been traced, except on the thoracic duct, which is surrounded by branches from the par vagum and great sympathetic.

The absorbents are much stronger in proportion to their size than the veins, so that they are capable of sustaining a greater weight of mercury; they are also extensible and very elastic.

These vessels are endowed with a contractile power, which may be excited, according to Cruikshank, by the application of an acid, and by exposure to cold air. It is also evinced by tying the thoracic duct or any other large lymphatic in a living animal, and then making a puncture below the ligature; on doing this, it is found that the fluid contents escape with a degree of force which is never seen, when a similar experiment is performed in the dead body.

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* Anat. of the Absorb. Vessels, p. 61.

† Mascagni, Vasor. Lymph. Historia, p. 26.

It is probable, that the absorbents are provided with the obscure kind of sensibility which is possessed by the other divisions of the vascular system.

SECTION IV.

OF THE LYMPHATIC GLANDS.

IN many parts of the body the course of the absorbents is interrupted by certain oval or round bodies, which have been named, from their supposed resemblance to acorns, *glands*. They are also called, in order to distinguish them from other parts which have received the same appellation, *absorbent* and *conglobate* glands; and by Chaussier they were denominated *lymphatic ganglions*, because it is thought by many anatomists, that they bear the same relation to their vessels, as the nervous ganglions do to the nerves.

They are principally situated in the trunk of the body, where their number, which is liable to variation, is very considerable. A few are found on the face; several are placed before and behind the ear; in the neighbourhood of the lower jaw they are clustered together; and on the sides of the internal jugular vein they form a kind of chain, and are therefore called the glandulæ concatenatæ colli. The absorbent glands abound in the chest; they are placed under the sternum, around the primitive blood-vessels, on the sides of the vertebræ, and some in the intercostal spaces; the greatest number lie on the lower part of the windpipe, and on the bronchial tubes. The abdomen incloses a great multitude of these bodies; the mesenteric are extremely numerous; the number of the mesocolic, lumbar, and iliac, is also very considerable. In the limbs the conglobate glands are not numerous. In the fore-arm, Mascagni has represented three or four; a few are placed in the upper arm, and several are contained in the axilla and on the side of the thorax. The leg has usually one gland; three or four are observed in the ham; a few are situated near the femoral artery; in the groin there are from eight to eleven glands; and, lastly, some are placed on the hip, underneath the gluteal muscles.

Their size and shape are various. Some are an inch in length, and others not more than two or three lines; in general the large glands are placed near the lymphatic trunks, and the smaller ones towards the branches. The majority of these bodies are oval or almond-shaped; but many are globular, and others are round and flat, or even triangular.

The absorbent glands are generally of pale red or flesh colour, which is of a deeper tinge in young than in old animals. The colour is not the same in all parts of the body. Thus the mesenteric glands are lighter than those of the limbs, and during the passage of the chyle through them, they are as white as milk; those of the liver are said to be yellowish, and it is well known that those of the lungs are blueish, or even quite black.

Each lymphatic gland is invested by a capsule, which is composed, as Dr. Hunter properly remarked, of condensed cellular membrane. It adheres very intimately to the substance of the gland, from which it cannot be separated without division by the scalpel. The external surface, on the contrary, is so loosely attached to the surrounding cellular tissue, that the glands in their healthy state are very moveable; but they become fixed and consolidated from the effects of disease.

The absorbent vessels pass into one or more of the glands which are situated in their course. It is stated by Mascagni, and his authority on this point has been generally admitted, that there is no lymphatic in the body which does not pass through at least one gland before it terminates in the large trunks. A different opinion was supported by Hewson, who thought there were lymphatics which entered the thoracic duct without having passed through any gland.* I believe that the statement of Mascagni, when it is confined to the larger vessels, is in most instances correct; but the recent discovery of the free communications between the lymphatic and venous branches, shews that it cannot be extended to the small vessels.

The absorbents which enter the glands are called *vasa inferentia*, and those which pass out of them, are termed *vasa efferentia*. Each of the former having approached within a quarter of an inch of the gland, divides into three or four smaller branches, which are subsequently continued into its substance, where they ramify in a very intricate manner. After being thus minutely divided, they re-unite and gradually become larger, till at length, at the distance of about a quarter of an inch from the opposite side of the gland, they all join to form the vas efferens.* The number and size of the lymphatics which enter any gland, are liable to great variation; sometimes there are only two or three, and at others there are twenty or thirty; the vasa efferentia are usually fewer in number, but larger in size.

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* That this sometimes occurs, is proved by an experiment performed by Cruikshank, in which the thoracic duct was injected from lymphatic vessels on the back, without injecting any gland.—*Anat. of the Absorb. Vessels*, p. 79.

When the blood-vessels have been successfully injected, it is observed that the absorbent glands receive a large supply of arteries. It also appears that these bodies are generally covered on the exterior by a minute network of lymphatic vessels. Nervous branches can be traced, although with difficulty, to the glands; and it is probable that they distribute filaments to the internal substance. The opinions of anatomists concerning the minute structure of the lymphatic glands are of a very unsatisfactory character. According to Hewson, Monro, Meckel, and others, the glands are principally made up of the convolutions of the vasa inferentia; whilst it was contended by Malpighi, W. Hunter, and particularly by Cruikshank, that they contain numerous cells in which the vasa inferentia terminate, and from which the vasa efferentia arise. Each party has appealed to anatomical observations in support of these theories, and each has also given plates in illustration of their ideas. The source of all this contradiction appears to have been pointed out by Mascagni, who ascertained that the lymphatic vessels, having freely divided and ramified within the glands, are dilated in some places and suddenly contracted in others, so that when they are injected they present the appearance of small eminences on the outer surface, and of cells in the interior. This observation has been confirmed by the dissections that were made a few years since by Beclard, which prove that the absorbents have an erectile disposition as they ramify within their glands. The use of these bodies is not known; but, as they are only possessed in the more perfect animals, it is probable that they render the absorbent system more complete.

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* Falconer, Exper. Inquiries, p. 53.

In the earlier periods of life the lymphatic glands are rather larger and softer than they are in the adult; they also contain more fluids. In old persons they become harder and smaller; but they never disappear, notwithstanding what has been stated on the contrary by some distinguished writers.

SECTION V.

FUNCTIONS OF THE LYMPHATIC SYSTEM.

THE most obvious use of the absorbent vessels is to convey the lymph and the chyle into the venous system; the former is the residue of nutrition, and the latter the product of digestion. These fluids are not merely emptied into the great veins of the neck, but likewise, as the observations offered at p. 315 sufficiently prove, into the veins of other parts of the body.

In the present day, the opinions of physiologists are divided as to the share which the lymphatics enjoy in the process of absorption. It has been generally believed since the time of the Hunters and Monro that these vessels are the only instruments employed in that function. In late years, the absorbing power of the lymphatics has been called in question; and many writers, particularly M. Magendie, have revived the ancient hypothesis of venous absorption. One of the most decisive experiments against the truth of the Hunterian doctrine was the following, which was performed on a dog previously made insensible by opium. The thigh was divided, with the exception of the femoral artery and vein; a quill was introduced into each vessel, and fixed there by two ligatures; the artery and vein were then divided between the threads, so that, in fact, the only connexion between the leg and the body of the animal was that established by the two quills, through which the circulation was maintained. Two grains of the upas tieuté were then introduced into the foot, which produced the usual effects, and caused death in about four minutes.* This result seemed to prove that the veins had absorbed the poison, and so conveyed it into the body. But there is a serious objection to this and similar experiments; for as there are free communications between the small lymphatics and veins, it is probable that the poisonous substance was absorbed by the former, and subsequently carried into some of the venous branches below the ligature.

The functions of the lacteals are not much more accurately known than those of the common lymphatics.

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* Compend. of Phy. p. 347.

Some physiologists, as John Hunter and Blumenbach, contend, that they not only absorb chyle, but also other substances, which are introduced into the intestinal canal. This opinion was supported by some experiments performed by Hunter. He injected milk, and other coloured fluids, into portions of the small intestine, and, in a short time, these substances were distinctly seen in the lacteal tubes, but no part of them could be discovered in the mesenteric veins. The exactness and accuracy of these investigations have been doubted by some of the most distinguished physiologists of the present day. M. Magendie has made a great number of experiments, from which he concludes the lacteals absorb chyle only, and that when any other substance is placed in the intestine, it is taken up by the veins. These ideas are strongly corroborated by the following experiment, which was performed by M. Segalas. A portion of the small intestine was insulated from the adjoining intestine by two incisions; all the arteries and veins belonging to it were tied, but the lacteals were carefully excluded from the ligature. A watery solution of the alcoholic extract of nux vomica was then injected into the fold of intestine, where it was secured by two ligatures. None of the usual effects produced by the poison were observed during the space of an hour; but, on untying one of the veins, the poisoning took place in six minutes.*

In reflecting on the opposite results which were obtained by Hunter and Magendie in their researches, it must be confessed that our knowledge of the function of absorption is doubtful and unsatisfactory. The following are, however, the conclusions which appear to be warranted by the facts we possess:—1. The lymphatic vessels are the principal, if not the only, agents of absorption. 2. The lacteal vessels absorb the chyle, and probably other substances, introduced into the intestines.* 3. Extraneous substances, which are artificially introduced into the internal parts of the body, soak through the various tissues, and, in this manner, find their way directly into the blood, through the coats of the blood-vessels. 4. It is probable that the veins take up the substances which are brought in contact with them, merely by this kind of imbibition, and that they do not absorb in the manner of the lymphatics.†

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* Journ. de Physiol. t. ii. p. 123.

The circulation in this system is slow, and generally uniform, but it is accelerated by external compression. Thus, if the thoracic duct be opened in a living animal, near its termination, it is found, that the flow of the contained fluids is quickened whenever the abdomen is compressed, either by the action of the respiratory muscles, or by the hand of the observer.

The principal power which effects this circulation appears to be the contractility of the lymphatic and chyliferous vessels; but their innumerable valves, and the pressure of the surrounding parts, materially assist in the process. Atmospheric pressure, as will be seen below, is also an agent which assists the absorbents in propelling their contents towards the chest.

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* I have no doubt that the lacteals are merely the lymphatics of the intestines, as it is certain, that, when they are not filled with chyle, they contain lymph. This fact is even stated by Magendie, who says, that when abstinence from all nourishment is prolonged beyond three or four days, the *chyliferous vessels become like the lymphatic, and are sometimes filled with lymph*. Comp. of Phy. p. 300.

† The reader will find some interesting observations on this subject in Mayo's Outlines of Phy. chap. 8, and in Dr. Elliotson's El. of Phy. p. 368, *et seq.*

We know but little of the cause which determines the various substances that are contained in the lymphatics and lacteals, to enter those vessels in the first instance. This phenomenon has been attributed to capillary attraction—to the sensibility of the absorbing mouths, and to the organic contractility they are supposed to possess—to imbibition—and, lastly, to atmospheric pressure. These hypotheses have been respectively supported by numerous observations and experiments, but none of them are sufficiently conclusive to establish the fact of any one of the above agents being the sole cause of absorption.

Although the pressure of the atmosphere does not appear to be the efficient cause of absorption, yet it is certain that it exerts a great influence on that process; so that if it be removed from any part of the body, the absorbing tubes are no longer able to perform their office. This fact has been satisfactorily proved by the very important experiments of Dr. Barry. He found, that when the most active poisons, as the concentrated prussic acid, strychnine, and upas tieuté, were introduced under the skin of living animals, their absorption and consequent baleful effects, were entirely suspended by the application of a cupping-glass over the place where the poison was lodged. It was farther ascertained, that if the application of the glass was continued for half an hour, it prevented absorption during the hour or two immediately succeeding its removal; and also, that when the symptoms of poisoning became apparent, they were speedily removed by the re-application of the cupping-glass. These investigations are of great practical importance in the treatment of poisoned wounds. In such cases Dr. Barry recommends, that the cupping-glass should be applied for at least an hour; that the wounded or abraded part should then be freely excised, after which the glass should be re-applied in order to remove any particles of the virus which may still remain; and, lastly, that the actual cautery should be employed when thought necessary, as in the bite of a rabid animal, but never under any circumstances before the second application of the cupping-glass.*

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* See Exper. Researches on Atmospheric Pressure, chaps. iii. iv. and vi.

CHAPTER FIFTH.

SECTION I.

OF THE GLANDULAR SYSTEM.

THE term *gland* has been so very vaguely and incorrectly used by anatomists, that it is difficult to define its exact signification, or to specify the organs to which it should be applied. Parts, which are the most dissimilar in structure, connexion, and function, such as the pineal, the thyroid, the thymus, the renal, and the lymphatic glands, have been indiscriminately classed together under the above denomination; and by this common name they are also confounded with organs of a truly glandular character, as the liver, salivary glands, &c. This arrangement is highly objectionable, because it misleads by implying a similarity of organization in parts which have not the slightest resemblance to each other.

The most comprehensive definition is that which admits, under the name of glands, all those organs which secrete any fluids from the blood; but this is too extensive, as it confounds together the recrementitial secretions, as those of the serous and synovial membranes, with the excrementitial fluids which are derived from mucous surfaces, or from the proper glands. Some writers have thought that a rounded form was essential to the character of a gland; this restriction is not, however, well founded.

It has been judiciously observed, that in order to distinguish the glands from all other organs, which they may resemble in their form and in their apparent texture, it is necessary to pay particular attention to their connexions. Bichat considers a *proper excretory duct* as essential to the character of a gland. Haase has adopted this idea, but he has committed a serious error by classing with the proper glands the lymphatic glands, which he supposes possess excretory ducts.

The term gland ought to be applied to those organs which are composed essentially of the union of the mucous and vascular systems, and which are provided with ducts, having usually a ramified disposition, and terminating on the internal or external cutaneous surfaces. This definition entirely, and, as I believe, properly, excludes the following bodies: the pineal, the pituitary, the thyroid, the thymus, and the renal glands; also the spleen, and the lymphatic glands.

It is extremely difficult to determine where the line of demarcation should be drawn between the mucous follicles and the glands. It has already been stated, that among the former, some are insulated and solitary; others aggregated or grouped together; and, lastly, that some are compound, or composed of the union of several bags, which have either a common orifice, or several openings. It is here that the difficulty exists; for there is no valid reason why the molar glands, the tonsils, and Cowper's glands, should not be ranged among the proper glands. The prostate and the vesiculæ seminales are still more closely allied to the glandular organs.

The most perfect glands are, the lachrymal, the parotid, the submaxillary, and the sublingual; the pancreas, the liver, the kidneys, the testes, and the mammæ. The ovaria of the female have also been included by Meckel and Beclard; but these bodies bear so little resemblance in structure or function to the preceding organs, that they cannot properly be assimilated with them.

The external form of the glands, although it presents many individual varieties, is usually round or oval, particularly in the early periods of life. Many of them consist of small lobes united to each other by a cellular, or even, as in the parotid gland, by a fibrous tissue; these are called *glandulæ conglomeratæ.* This lobulated arrangement extends to the interior of some glands, as the lachrymal and salivary; it is also observed, but not so distinctly, in the mammæ. The testicles have a lobulated appearance, but of a different character, which is owing to the existence of ligamentous septa. The liver is lobulated on the external surface only, and the kidneys merely in the fœtus.

SECTION II.

ORGANIZATION OF THE GLANDS.

THE glands, which are amongst the most vascular parts of the body, present variations as to the quantity of blood which each individually receives; the kidneys, however, surpass all the others in the great capacity of their arteries. The length, the course, and the mode of distribution of the blood-vessels are equally variable. They either penetrate the surface of the organs by several branches, as in the salivary glands; or, as most usually happens, they enter in single trunks at fissures, which are placed, as in the liver and kidney, in the least exposed part of the gland. The difference in the relative capacity of the arteries and veins, which is so striking elsewhere, is very little marked in the glands; because a considerable part of the blood is changed into the secreted fluid, and is carried away by the excretory ducts. The lymphatic vessels are numerous, and in some instances, as in the testis, they are very large.

The nerves are very small, and often constitute plexuses; they are in most instances derived from the system of the sympathetic, but in part from the cerebro-spinal axis.

Every gland has an excretory opening, which is either simple, or the termination of a canal which is ramified in the interior. The little orifice of the sebaceous or mucous follicles, which conveys to the external surface the secreted fluid, is the most simple example of an excretory duct, and may be received as the type of the entire class. Some of the more complicated of the mucous follicles, as the amygdalæ and Cowper's glands, have excretory canals; but they are short and are not ramified. In the prostate and vesiculæ seminales the emunctories are still more developed. The ramified and intricate canal to which the name of excretory duct is more particularly applied, is, however, only possessed by the proper glands. Each of these tubes begins by very fine roots which unite together like the branches of veins, and ultimately constitute one or more large ducts, which issue from the organ, and open obliquely on the adjacent part of the mucous membrane.

This peculiar mode of termination allows the flow of the fluids from the gland, but not in the retrograde direction.

The duct of the kidney, the ureter, begins from an enlarged receptacle, called the pelvis; it afterwards terminates in a capacious reservoir, named the urinary bladder. The hepatic duct has likewise connected with it, a peculiar reservoir, *vesicula fellis*, in which the bile is collected, and where an absorption of the watery parts of that humour takes place. It has also been said by many anatomists, even in the present day, that the vesiculæ seminales are receptacles for the semen, and consequently that they have the same relation to the testicles that the gall bladder has to the liver; but this statement is incorrect, as the vesiculæ are undoubtedly proper secreting bodies. The excretory tubes of the mammæ, the galactophorous or lactiferous ducts, are remarkably enlarged towards their extremities, so as to retain the milk till they are forcibly extended; and in this manner they serve the office of a reservoir by receiving the secreted fluid.

The excretory ducts consist of a mucous membrane, which gradually becomes thinner as it penetrates into their ramifications. This membrane is covered, in most instances, by a dense and fibrous texture, which is seen in the parotid duct, in the hepatic ducts, in the ureter, vas deferens, &c.; in other ducts, as the lactiferous, the surrounding structure is of an erectile character.

The constituent parts are joined to each other by cellular tissue, which is subject to considerable variation with respect to its quantity and disposition in different glands. Each of these organs is also invested by a proper membrane, which is either of a cellular or fibrous character. In some instances, as in the liver and the testicles, there is an additional serous covering.

The opinions of anatomists concerning the minute structure of the glands, have for a long time been influenced by the celebrated theories of Malpighi and Ruysch. The former thought that there were small vesicles or follicles, placed between the termination of the secreting vessels and the commencement of the excretory tubes, in which the last vascular ramifications were placed. This doctrine was received till Ruysch, who was so justly distinguished for the success and delicacy of his injections, called it in doubt. This skilful anatomist contended that these supposed vesicles consisted altogether of an interlacement of minute vessels, in which the last terminations of the arteries were continuous without interruption with the roots of the excretory tubes. According to the former hypothesis the gland is nothing more than a mass of follicles; whilst according to the latter, it is only an exhalant membrane, folded and doubled on itself a great number of times.

It is almost impossible to decide between these conflicting statements, in consequence of the complicated structure of the glandular organs. There is, however, reason to believe that both Malpighi and Ruysch applied their theories too exclusively, for we can scarcely suppose that such dissimilar bodies as the pancreas and kidney, possess exactly the same kind of texture. On the whole the balance of evidence turns in favour of the existence of follicles. This assertion is supported by an extended examination of the glands in the inferior animals, which proves that these organs are composed of canals which, whether simple or compound, begin from cul de sacs, and are surrounded by numerous blood-vessels. The type of the glandular formation is exhibited in the simple mucous glands, which consist of single sacks or follicles. In order to comprehend the structure of the most compound gland, we have only to figure to ourselves these sacks prolonged and ramified, with their branches interlaced with those of the blood-vessels, but without there ever being a direct communication between the sanguiferous vessels and the excretory ducts.* In admitting the general truth of this doctrine, we must still recollect that Ruysch is correct in stating that each glandular grain, and also the entire gland, consists of the mixture and interlacement of delicate vessels with the origins of the excretory duct; but he is wrong in saying that the excretory tubes are the continuation of the arteries. The effects of minute injection and of careful inspection, render it probable that the opinion of Malpighi applies more particularly to the granulated glands, such as the parotid and the pancreas; and that the theory of Ruysch extends to those organs which, like the liver, the kidneys, and the testes, are provided with a more evident vascular and tubular structure.

SECTION III.

FUNCTIONS OF THE GLANDS.

THE functions of these organs can only be regarded in a very general manner, because each gland has an especial use in the economy, the history of which belongs to physiology. The glandular secretions are, like all others, derived from the blood; so that they are only peculiar by their mode of separation, and by the compound nature of their chemical analysis. It is impossible to penetrate into the wonderful mechanism of secretion, by the operation of which, such totally different fluids, as the saliva, the milk, the semen, and the urine, are all formed from the blood. It is useless to attempt an explanation by physical or by chemical causes exclusively. That chemical actions must take place is certain, but they are chemical actions which are caused and regulated by the principle of life, so that they cannot be imitated by art. The extent of our knowledge only informs us, that the materials of the glandular secretions are in all instances except one, that of the bile, furnished by the arterial blood; that in the extreme divisions of the arteries, the secreted fluid, whatever it may consist of, is separated from the circulating fluid; that it afterwards is conveyed into the commencement of the excretory duct, where it becomes apparent to the senses; and, lastly, that the residue of the blood, now altered in its character, is returned by means of the veins.

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* Meckel, Manuel d'Anat. t. i. p. 515.

The power of the nervous system has a most important influence on glandular secretion. Thus we learn from common observation, that the emotions of the mind, which act on the glands through the medium of the brain and nerves, may either increase, diminish, or altogether suspend the secretion of any glandular fluid. And again, it has been proved by the experiments of Mr. Brodie and Dr. W. Philip, that the division of the nerves belonging to a secerning organ deranges or destroys its power. It has also been ascertained, that the application of a ligature to the veins of a gland, considerably augments the quantity of its secretion.

The development of the glandular system in the human embryo, corresponds in many essential points with the permanent organization of the inferior animals. This curious fact is illustrated in the formation of the excretory canal, which in the commencement is loose and floating, as it is in insects; and at a rather more advanced period the glands are lobulated, as they are in the arachnides and crustacea. These organs are generally very large in the fœtus and infant; but as they afterwards remain nearly stationary in size, and as the bulk of other parts of the body is increased by growth, their relative proportion is considerably diminished. The testes change their situation previous to birth, and at the period of puberty they are greatly developed; and at the same time in the female, the mammæ are very much increased in size and fulness. After the cessation of menstruation, the latter glands become smaller, and occasionally indurated or schirrous; and in old men the testicles are similarly affected.

CHAPTER SIXTH.

OF THE CARTILAGINOUS SYSTEM.

CARTILAGE is distinguished from every other texture, by its pearly whiteness, firmness, great elasticity and smoothness. When divided it appears to be homogeneous, and to have neither fibres nor laminæ, but by prolonged maceration a fibrous structure can be demonstrated.

Anatomists have generally comprehended, under the term of cartilage, parts which exhibit many variations in their structure. These differences which have been long remarked, induced Bichat to divide the cartilaginous bodies into cartilages and fibro-cartilages; and as this division seems to be well founded, I have adopted it in the classification of the solids. In accordance with this arrangement, I shall only include under the term of cartilaginous system, the cartilages which cover the ends of the bones in the moveable articulations and those appended to the ribs. The cartilages of the nose, the ear, the windpipe, &c., which partake of the properties of true cartilage and of ligament, will be considered after the fibrous organs have been described.

SECTION I.

OF THE CARTILAGES.

THESE bodies are divided into the *temporary* and the *permanent*. The former, which supply the place of bone, exist only in the fœtus and in young persons; they constantly and regularly disappear in proportion as ossification advances. The latter, which are met with in all periods of life, cover or incrustate the extremities of the bones in the moveable articulations; and in the instance of the ribs, they assist in the formation of the thoracic cavity. The temporary cartilages will be described with the osseous system.

Those of the joints are named *articular* or *diarthrodial* cartilages; each of them consists of a layer which corresponds in shape with the process it covers. The thickness of this plate, varying from one or two lines to the fraction of a line, is generally proportioned to its size; but it usually happens, that the elastic matter is accumulated on the centre of convex surfaces, and on the circumference of those which are concave.

The adherent surface of these cartilages is so intimately connected to the bone, that it is impossible to effect a complete separation without the assistance of maceration. The exact means by which this union is accomplished, are not known, but it is certain that in the adult, the cartilage is not a prolongation of the bone, although in the early periods of life there is only a cartilaginous mass in the place of the latter. It has been justly observed by Bichat, that if there were such a continuity, it ought to be perceived when the bone is deprived of its earthy part by diluted acids; but instead of this, it is seen that the cartilage is constantly detached by the action of the acid, either in one entire piece or in fragments.

The free surface owes its polished appearance to the synovial membrane by which it is covered; the connexion between the two structures is so very close, that it is almost impossible to separate one from the other. This circumstance has induced some anatomists to deny the reflexion of the serous membrane of the joint over the cartilage. The incorrectness of this opinion has been pointed out in a preceding chapter.*

The cartilages of the second class, which are called the *costal*, are the largest and thickest of the body; they form cartilaginous prolongations to the osseous ribs. The cartilage of the first rib is immovably fixed by the insertion of its fibres into the side of the sternum; those of the six following are joined to the latter by diarthrodial articulations; the three next are connected in a similar manner to each other, and the two inferior are attached to muscular structure.

The costal cartilages are covered by a dense membrane, which is called the *perichondrium*; it adheres very firmly to their surface, but not so closely as the periosteum to the bones. It serves to convey the small blood-vessels which penetrate into these bodies.

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* See p. 145. The valuable observations of Mr. Brodie forcibly illustrate the importance of distinguishing between the synovial membrane and the cartilage which it invests. He has shewn that the two textures are subject to distinct diseases, which may be detected in their commencement attacking either the membrane or the cartilage, but which afterwards generally extend their ravages to all parts of the joint. This excellent work places in a perspicuous light the importance of investigating the nature and treatment of disease according to the structure of the parts implicated. Pathological and Surgical Obs. on the Diseases of the Joints. See particularly Chaps. 1, 2, and 4.

SECTION II.

ORGANIZATION OF THE CARTILAGES.

THE cartilages, when they are divided, seem to be homogeneous, and without any appearance of fibres, vessels, or nerves; but when they are carefully prepared, a fibrous texture becomes apparent, and the phenomena which they exhibit in health and disease prove the existence of a vascular and nervous structure. The proper cartilaginous texture consists of an immense number of whitish fibres, which can be seen in the articular cartilage after it has been macerated during six months; they are also rendered apparent by boiling, provided it be not prolonged so far as to cause a solution of the animal matter. These fibres, which pass in a direction perpendicular to the bone, are distinguished by their great firmness, which is inferior only to that of the osseous structure; they are also highly elastic, and at the same time so brittle, that if they are forcibly bent, they give way and break. The tissue of the costal cartilages is very obscure, and at first sight homogeneous; but these bodies, after a prolonged maceration, separate into oval layers or plates, which are united by oblique fibres sent reciprocally from one to the other; these laminæ are themselves composed of radiated fibres.

The cellular tissue of the cartilages, owing to its extreme condensation, is with difficulty distinguished; it can, in fact, only be seen after a prolonged maceration, or the action of boiling water has reduced the cartilage into a soft and cellular substance.

The arteries are so extremely minute that they do not receive red blood; a colourless and nutritive fluid circulates, however, in the cartilage, although some writers have contended that it is a non-vascular structure. The existence of vessels is satisfactorily proved by the deposition of new particles during growth, and by the yellow colour which these bodies assume in jaundice.* Lymphatics cannot be detected, but their presence is rendered evident by the absorption that takes place in cartilage in the process of ossification, and also in many diseases. It has been remarked that the power of the absorbents is greater in the osseous than in the cartilaginous, or rather in the fibro-cartilaginous texture.† These organs, in their healthy state, are not endowed with sensibility, but as they become painful in inflammation, we must conclude that they receive nerves, although they cannot be traced by the eye.

The chemical composition of cartilage has been carefully examined, especially in this country. It was stated by Haller, that it consisted of gelatine and earth; but the investigations of Mr. Hatchett and Dr. Davy prove that there is little, if any, jelly. These chemists conclude that cartilage is principally composed of condensed albumen, and the latter also has detected a small portion of earthy phosphate. The following is the analysis of Dr. Davy:—Albumen, 44·5; water, 55·0; phosphate of lime, ·5 = 100.‡ By the continued action of boiling water most of the cartilages may be dissolved; they are also readily dissolved by nitric acid, and by a strong solution of potash. When a piece of cartilage is dried, it becomes yellow, semitransparent, and very brittle; if it is then placed in water, it regains in a few days its white colour, opacity, and flexibility.

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* Bichat, Anat. Gen. t. ii. p. 238.

† Brodie, l. c. p. 301.

‡ Monro's Anatomy, vol. i. p. 69.

SECTION III.

PROPERTIES AND FUNCTIONS.

THE cartilages are distinguished by the great firmness and solidity of their texture, which enables them to resist the force applied to them in the various articulations. They are also characterized by their elasticity, on which property their specific use in the economy depends.

The vital properties are very obscure in this system, but we cannot therefore suppose that cartilages are dead or inorganic substances. They are not capable of contracting, and it is probable that they do not possess animal sensibility in the state of health. They are, however, susceptible of painful impressions when they are irritated in an unusual manner; there is an instance of this in the severe suffering which is occasionally experienced from the presence of loose bodies in the joints.

The functions of these organs depend, like those of the osseous system, with which they are closely allied, on their physical properties. Their elasticity allows them to yield in the shocks to which the body is exposed, in the ever varying movements of the animal frame; and in this manner they defend the bones from fracture and displacement, and at the same time protect the great centres of the nervous system from those injurious concussions to which they would otherwise be liable. In this important office, which is almost their sole use, they are frequently assisted by some of the bodies included in the fibro-cartilaginous system. The costal cartilages powerfully assist in expiration, in consequence of their elastic reaction depressing the ribs when the contraction of the inspiratory muscles ceases.

SECTION IV.

DEVELOPMENT OF THE CARTILAGES.

IN the embryo and fœtus these bodies, in consequence of the large quantity of water they contain, are soft, semi-fluid, and transparent, like jelly or glue. In the infant they are still nearly colourless, soft, and but slightly elastic. In the adult they gradually acquire consistence, whiteness, and opacity; it is also during this period of life, that they are so eminently elastic. In old age they become more yellow and firm, and then lose a considerable portion of their flexibility and elasticity. The cartilages of the articulations are very seldom ossified. The costal cartilages, after the adult age, become homogeneous; and subsequently, osseous plates of unequal thickness are produced between them and their opake perichondrium, and at length they are converted into bone. This change most commonly begins in the cartilaginous extremity of the first rib, and afterwards in the ribs below. It does not, however, constantly occur, as these cartilages have been seen without any ossification in men of one hundred and thirty or one hundred and fifty years of age.

CHAPTER SEVENTH.

OF THE FIBROUS SYSTEM.

THE tissues which have been described in the preceding chapters, are composed of the cellular membrane and of its various modifications. But the parts which are included in the system now to be considered, have so little external resemblance to the cellular substance, that some excellent anatomists have denied the existence of any similarity between them. There is, however, little doubt that the *albugineous fibre* of Chaussier* is simply a condensed form of the common cellular fibre.

The term of *fibrous system* was applied by Bichat to a numerous class of organs that had previously been investigated only in an insulated, and consequently, imperfect manner. This word ought not, in strict language, to be confined exclusively to the system under consideration, because the fibrous structure is as perfectly developed in the muscles and nerves, as in the tendons and ligaments; but as the former are distinguished by other and more appropriate denominations, and especially as it would be difficult to suggest a term more expressive of the peculiar character of this tissue, I shall retain it for the sake of convenience.†

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* See pp. 58 and 61.

† This tissue has been designated by the names of the *albugineous, ligamentous, tendinous, aponeurotic,* &c.

SECTION I.

OF THE FIBROUS ORGANS IN GENERAL.

THE following is an enumeration of the parts which are included in this system: 1. The periosteum and perichondrium. 2. The muscular aponeuroses or fasciæ. 3. The fibrous sheaths of the tendons. 4. The fibrous membranes of certain organs, viz. the dura mater of the brain and spinal cord; the tunica sclerotica; the reflected portion of the pericardium; the tunica propria of the kidneys; the tunica albuginea testis; the fibrous sheath of the corpora cavernosa penis et clitoridis; and lastly, the covering of the ovarium. 5. The ligaments. 6. The tendons.

Although the configuration of these organs is various, yet two forms generally predominate. In the first, the length and breadth are nearly equal; the parts which possess this form are called *membranæ fibrosæ*, of which order are the periosteum, the dura mater, the capsular ligaments, &c. In the second, the length greatly exceeding the breadth, the fascicular form predominates; the parts which have this form, *organa fibrosa fascicularia*, consist of certain tendons and ligaments.

Notwithstanding the different parts of this system, are so much diffused in the animal frame, and apparently so independent of each other, they are, with a few exceptions, strictly connected together, so as to constitute a continuous whole. Anatomists, even before the time of Galen, thought that the membranes of the body were continuous, and that they might be traced from the pericranium. A similar opinion was entertained by the Arabians, who appear to have regarded the membranes of the brain as the source of all the others. It is to these erroneous ideas that we owe the terms of dura mater and pia mater; these words are still employed in anatomical descriptions, although their original meaning has long ceased to be attached to them.

A careful examination of the connexions of the fibrous system, will shew that Bichat was correct when he pointed out the periosteum as its common centre, by which its different parts are joined together. In fact, if we except the perichondrium of the larynx and windpipe, and the fibrous membranes of some glandular bodies, it will be easy to demonstrate the above communication. Thus the cranial portion of the dura mater is continuous with the periosteum at the openings of the base of the skull; and the spinal process of the same membrane, although not directly connected with the periosteum of the vertebræ, is yet at the lower part of the canal joined by some ligamentous filaments to the covering of the sacrum. The tunica sclerotica is united with the dura mater, by means of the sheath which the latter affords to the optic nerve; and the fibrous membranes of the penis and clitoris interlace with the periosteum of the ossa ischia. Lastly, the fibrous sheaths of the tendons, the muscular aponeuroses or fasciæ, the tendons and ligaments, are all intimately attached to the periosteum, and, through its medium, to the bones.

SECTION II.

ORGANIZATION OF THE FIBROUS SYSTEM.

EACH of these organs consists of an assemblage of distinct whitish or greyish fibres, which are nearly inelastic; they are also insensible, and are distinguished by their power of resistance. In most parts of the body the fibres are disposed in a regular manner, and pass, more or less, in a parallel direction; in other places, they cross and interlace with each other; and, in some instances, they form layers, which are superposed on each other so as to produce a most intricate fibrous web; this is the arrangement in the dura mater, in the irregular ligaments of the pelvis, in some of the aponeuroses, &c. The fibres of several tendons and ligaments are so small and so closely united together, that they cannot be perceived, although they become apparent by maceration. It has been already stated, that the ultimate fibres, which are extremely minute, are formed of the cellular substance very much condensed.

The different fibrous organs are surrounded by a quantity of cellular tissue; in those which possess distinct fasciculi, it forms sheaths around them, and even the fibres are enclosed by the cellular membrane, which becomes apparent by maceration.

The blood-vessels of this system are not met with in the same quantity in all parts of it. The periosteum and the dura mater are very vascular; but the greater number of their vessels are provided for the supply of the bones; the fibrous tissue, in general, receives but few arteries and veins. Those which do exist may be displayed, after they have been filled with a fine injection, by drying the part and then plunging it in spirits of turpentine, in order to render it transparent. Lymphatic vessels can only be perceived in a few of these organs. It is generally impossible to trace nerves, but they have been seen in some parts;* and as the periosteum and similar structures become very sensible in various diseases, it must be admitted that they have also communications with the nervous system.

The chemical composition resembles that of the cellular tissue. The basis of these organs appears to be coagulated albumen, united to different proportions of jelly and mucus; they contain no earth, and only a minute quantity of saline matter. By desiccation the water of the fibrous tissue is evaporated; and it then becomes hard, transparent, yellow, and fragile. It resists maceration for a very long time, but gradually it is rendered soft and flocculent on the surface; the fibres are separated, and at length it is reduced into a pulpy cellular substance. It is dissolved by the mineral acids.

SECTION III.

PROPERTIES OF THE FIBROUS ORGANS.

THIS tissue in its recent state possesses but little elasticity, although when it is dried, this quality becomes very remarkable.

The force of resistance to rupture is enormous, and it is owing to this property that the fibrous organs are not susceptible of any considerable or sudden extension.

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* Monro, on the Nervous System, p. 66.

Thus in inflammation beneath aponeurotic or ligamentous structures, in consequence of their unyielding nature, they compress and strangulate the parts which they cover. But if the force applied be greater than the resistance of these organs, they give way and are lacerated, as happens in the various dislocations. On the contrary when the distending force acts slowly, they are not ruptured, but are extended; this is observed in dropsy of the pericardium, or of any of the articulations. They are not capable of suddenly contracting, although they are restored in part to their original state after they have been gradually distended.

These parts possess no animal contractility, so that irritation produces no alteration in their state. Their sensibility has been doubted by many writers, and in the ordinary acceptation of that word, this opinion is probably correct; because if a ligament or tendon be pricked with a needle or cut with a knife, no pain is excited. But it is necessary to bear in mind that the degree and the kind of sensibility, vary in different organs according to the particular functions they have to perform. The ligamentous, tendinous, and other similar parts, have no need of that exquisite sensibility which is so essential to the external surface of the body, because they are protected by their deep situation from any direct mechanical irritation; but as the greater part of these organs are liable to be distended and twisted in the violent movements of the limbs, it is necessary that they should be endowed with that species of sensibility, which will enable them to warn the percipient principle when the irritation is carried to an injurious extent. The following experiment illustrates the force of these observations: if one of the joints be completely exposed in a living animal, by removing the surrounding parts, and particularly the nerves, it is found that the ligaments may be irritated by chemical or mechanical agents, without the animal giving any expression of suffering; but if the same ligaments are forcibly distended and twisted, great pain is produced, and the animal struggles violently.*

The uses of the fibrous structures will be noticed in the ensuing sections.

In the embryo this system is, like all other parts, soft and gelatinous. In infancy it retains much of its softness and flexibility; it receives a considerable number of blood-vessels, is of a blueish colour, and is easily dissolved in boiling water. In the adult these organs become more fibrous, dense, and resisting; and these properties are still farther developed in old age, when the ligaments, tendons, &c., losing something of their white and polished appearance, assume a yellowish colour.

Having considered in the preceding pages the common characters of the fibrous system, I shall now describe the peculiarities of its several parts.

SECTION IV.

FIBROUS ENVELOPES.

MANY organs in the body are invested with a strong and ligamentous structure, which presents variations in its mode of connexion, and in the functions which it fulfils.

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* Bichat, Anat. Gen. t. ii. p. 264.

OF THE PERIOSTEUM.

This dense membrane, of which the dura mater is merely a process, surrounds the bones in all their extent, except at their articular extremities; in these places, although the periosteum is interrupted in its connexion with the bones, it is continuous with another division of the fibrous system, viz. the ligaments.

The external surface is rough and flocculent; it is confounded with the surrounding cellular tissue, excepting where it covers the bones of the nasal fossæ, of the sinuses, and of the cavity of the tympanum, in which places it is united to the mucous membrane; there is also an exception in the mouth, where it is connected with the dense structure of the gums and palate. The outer surface of the dura mater is covered by the arachnoid both in the skull and in the vertebral canal.

The inner surface is joined to the bones by means of innumerable threads or prolongations, which line the canals, transmitting the nutritious vessels towards the interior. These filaments are more numerous on the spongy ends of the long bones, and on the surfaces of the short ones, than in other places. They adhere much closer in the adult, and especially in old age, than in infancy.

The thickness of the periosteum is variable; but in general it is proportioned to the vascularity of the bones, and to the age of the subject.

The fibres of this membrane are disposed nearly in the same direction as those of the bones, but in the dura mater they have a very irregular arrangement, and being placed over each other, they may be divided into layers, of which two are very distinct.

The uses of this membrane are various; in the first place, it covers the bones and assists in their nutrition by supporting the blood-vessels; it also serves as a medium for the attachment of the ligaments, tendons, aponeuroses, &c., to the osseous system; and lastly, in infancy, it unites the epiphyses to the bones.*

The perichondrium is the investing membrane of the cartilages† and fibro-cartilages; it is so similar to the periosteum, that it is not necessary to give any detailed history of it. The principal difference relates to the vascularity, which is much less than in the preceding structure. The perichondrium fulfils the same functions with respect to the cartilages, that the periosteum does to the bones; it also gives to those among the fibro-cartilages which are thin and flexible, a resistance and tenacity that would otherwise be defective.

OF THE ENVELOPES OF THE MUSCLES, OR APONEUROSES.

The term of aponeurosis has usually been applied not only to the fibrous coverings of the muscles, but also to certain tendons, as those of the abdomen, which are distinguished by their great breadth and extent. Notwithstanding the high authorities who have given this signification to the above word, I believe it will be preferable, for the sake of clearness and distinction, to restrict its application to the investing structure of the muscles; with the meaning thus confined, the term of aponeurosis may be considered as analogous with that of *fascia*.

The muscular envelopes are of two kinds: 1. Those of the limbs. 2. Those of the trunk.

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* The connexion of this membrane with the process of ossification will be noticed in the chapter on the osseous system.

† See p. 339.

The aponeuroses of the extremities are fibrous membranes, which surround the muscles, and by binding together their fibres, they prevent any displacement of them during the powerful contractions to which they are subject. The muscular fasciæ are usually disposed in the form of sheaths, which incase the extremities, and thus constitute a firm and resisting investment of the body, placed beneath the more yielding covering of the skin. It results from this disposition, that their external surface is connected with the subcutaneous cellular and adipose tissues, and also with the superficial veins, lymphatics, and nerves. Their internal surface corresponds to the muscles, to which they are usually joined by a lax, cellular structure; but in some places the muscular fibres are intimately attached to the aponeuroses, and in fact arise from them. This surface also frequently furnishes processes or prolongations, which separate the muscles from each other, and at the same time give origin to their fibres; these partitions are called *intermuscular ligaments*.

The fasciæ are firmly united to the ridges and processes of the bones, and also to the annular ligaments of the hand and foot. They are composed of one or of several layers of the fibrous tissue, variously disposed; between their fibres, openings are formed for the passage of vessels and nerves. Their thickness is generally proportioned to the number and power of the muscles they cover. The aponeuroses are almost invariably provided with extensor muscles; some of which are proper to them, whilst others are only connected with them by means of expansions sent off from their tendons. There are examples, of the first class, in the insertion of the tensor vaginæ femoris in the fascia lata, and of the palmaris longus in the fascia palmaris; and of the second, in the connexion of the tendon of the biceps cubiti with the fascia of the fore arm, and of the gluteus maximus with that of the thigh. These muscles brace the fasciæ in the movements of the limbs, and thus increase the power of the muscles placed beneath them.

The aponeuroses of the trunk, which are always partial, cover certain muscles, and in part even surround them. The following are the principal; the temporal fascia, the deep fascia of the back, the fasciæ of the neck, of the transversalis muscle, of the pelvis, of the perineum, &c. The superficial fascia of the abdomen, which is enumerated by some anatomists, does not strictly belong to the system under consideration; it is composed of cellular membrane, moderately condensed.

The use of the aponeuroses is principally to support and strengthen the muscular system, in which office they are materially assisted by the tendinous sheaths and ligaments; they also afford points for the origin of fibres; lastly, they serve in some parts to protect from external pressure and injury, the vessels and nerves; and they likewise appear to favour the venous and lymphatic circulation, and in this manner they prevent varicose enlargement of the deep-seated veins, and effusion into the cellular tissue.

OF THE SHEATHS OF THE TENDONS.

These sheaths have been divided by Bichat* into two classes, viz. the general and the partial; but his account of these structures is, in some of its details, imperfect.

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* Anatomie Gen. t. ii. p. 285.

The fibrous sheaths in several places consist of canals in which the tendons are enclosed; and, in other parts, simply forming rings and bands, they are called annular ligaments. The former are firmly attached to the bones, and are lined by synovial membranes, which are also reflected on the tendons as they pass through the sheaths: this arrangement is very evident in the thecæ of the fingers and toes. The latter consist of strong bands extended over the tendons, which they retain in their situation. Some of them are divided into several processes by fibrous septa, which are fixed to the projecting ridges of the neighbouring bones; and in this manner several distinct sheaths are formed, for the transmission of as many tendons, which are lined by the synovial membrane; there is an example of this disposition in the posterior annular ligament of the hand, and in the annular ligament of the ankle. Others are not subdivided, so that the tendons are contained in one sheath, although as they pass through it, they are covered, and in a degree separated from each other, by the synovial membrane; this is the arrangement in the anterior ligament of the hand.

These sheaths are very thick and firm, especially in the direction of flexion; they are composed of distinct transverse fibres, which become thinner opposite the articulations, where indeed, as in the fingers, they sometimes entirely disappear.

They serve to maintain the tendons, particularly those of the long muscles, in their places during the action of the fleshy fibres, and in some instances, as in the pulley of the trochlearis, they alter the direction of the tendons, and thus modify the movement of the parts to which they are attached.

FIBROUS ENVELOPES OF CERTAIN ORGANS.

These consist of very dense membranes, which closely invest, and, in many instances, adhere to several important organs. The following structures may be enumerated as belonging to this class: the dura mater, the tunica sclerotica, the fibrous portion of the pericardium, the tunica propria of the kidney, the tunica albuginea testis, the fibrous coat of the ovarium, and the sheath of the corpora cavernosa penis and clitoridis. Bichat, and most of the continental writers, also include the proper coat of the spleen; but this appears to be formed merely of condensed cellular membrane. It is doubtful if the thick coats of the ureter, of the vas deferens, and of the parotid duct, which possess a distinct fibrous structure, ought not to be included with the preceding parts. The only objection to such an arrangement is, that these tubes appear to possess a contractile power, which is entirely wanting in the proper fibrous tissue.

Some of these tunics, as the dura mater, the fibrous portion of the pericardium, and the tunica albuginea testis, are intimately united with the serous system, so as to form *fibro-serous membranes*, or, as they are called by Beclard, *compound fibrous membranes.*

In some instances numerous processes are sent by the ligamentous envelopes into the substance of the invested organs. This is seen in the fibres which penetrate into the testicle from its proper coat; and in the septa prolonged into the penis from the sheath of the cavernous bodies. In other places there is only a connexion by cellular tissue; as in the examples of the tunica sclerotica and the tunica propria of the kidney; lastly, the dura mater and the pericardium are entirely separated from the brain and the heart by the lining serous membrane.

The fibrous envelopes are provided for the support and protection of the different parts to which they are attached.

SECTION V.

OF THE LIGAMENTS.

THESE bodies, which form a very important class of the fibrous system, connect the bones, and occasionally the fibro-cartilages, with each other. The same name has been improperly applied to many other parts, especially to the folds which are formed by the mucous, serous, and synovial membranes. The true ligaments are fixed to the bones through the medium of the periosteum, and the union is so remarkably strong that a continued maceration is required to destroy it; but in the infant a separation is more readily accomplished.

These organs may be divided into the articular and non-articular; the first are placed around the different articulations, to the formation and completion of which they importantly contribute; the second are unconnected with the joints.

The articular ligaments are distinguished by their form into the capsular and the funicular. The former, which are also called *fibrous capsules*, consist of cylindrical bags, lined internally by the synovial membrane. They are confined to the scapulo-humeral and ilio-femoral articulations, in which they permit every species of motion. In some other joints, as in the elbow and wrist, there are synovial capsules, strengthened by ligamentous fibres, so as to constitute imperfect fibrous capsules.

The funicular or fascicular ligaments are extremely numerous; their form is various, but they are usually round or flat. They are for the most part placed on the exterior of the joints, although a few are situated in the interior. The external cords are principally placed on the sides, and are consequently distinguished by the name of *lateral ligaments;* some are placed before and others behind the joints, and are therefore called anterior and posterior ligaments. All these cords are attached to the bones by their two extremities; and each of them has its internal surface covered by the synovial membrane, and the external by the cellular tissue. The internal ligaments are only observed in the hip and knee joints; they are placed within the respective capsules, and are surrounded by the synovial membrane, which is reflected on to them at their extremities.

The ligaments of the immovable articulations differ from the preceding by the irregularity of their fibres, and by being unconnected with the synovial membrane.

The non-articular ligaments are frequently attached by both their ends to one bone, such are the ligaments of the scapula; others on the contrary, are connected with two or more bones; of this species are the sacro-ischiatic and interosseous ligaments.

The principal use of these organs is to secure the different parts of the skeleton to each other; they also serve to complete the joints, and to determine the kind and extent of motion. In some parts of the body, as in the pelvis, they form openings for the passage of blood-vessels, nerves, and muscles; and, lastly, they give origin to muscular fibres.

SECTION VI.

OF THE TENDONS.

THE tendons consist of that part of the fibrous system which is united to the muscles. They are, with a few exceptions, attached on the one hand to those organs, and on the other to the bones; a few of them are joined by both of their extremities to muscles, and are thus placed in their substance; these, which are called *tendines intermedii*, are met with in the digastric muscles.

The forms of these bodies are various, most of them consist of elongated cords, which are usually flattened or rounded; these are the tendons properly so called: others amongst them, which are broad and membraniform, are described by many anatomists with the aponeuroses, under the name of aponeuroses of attachment. Some of the tendons have the form of arches; an arrangement which is admirably adapted to give passage to blood-vessels, in such a manner as to avoid injurious pressure when the muscles contract; the transmission of the aorta through the diaphragm, is a striking illustration of this mechanism. It frequently happens that a tendon has the form of a cord for a considerable part of its extent, and then at one or both of its extremities, becomes expanded into a membrane. Sometimes a single tendon divides into several others, which pass separately to their insertion; this is the arrangement in the flexor longus digitorum pedis; and in other instances, two tendons unite to form one, as in the junction of the gastrocnemei, where they produce the tendo Achillis.

The direction of these bodies usually corresponds with that of the muscles to which they are attached; but in many parts of the body, their course is altered by projecting processes of bone, and sometimes they are reflected at nearly a right angle; there are examples of this disposition in the tendons passing behind the malleoli, in the tendons of the peroneus longus, of the circumflexus palati, &c.

Every tendon in the body is intimately connected by one of its extremities with the muscular fibres; it has even been asserted, that there is a real identity and continuity between the two parts; the only difference depending on the condensed state of the former. As far as the proper muscular structure is concerned, this statement is incorrect; but it is certain, that there is a close connexion between the tendon and the cellular tissue of the muscle; indeed it is probable, that the former consists of the delicate sheaths of the fibrillæ belonging to the latter, which, on quitting the muscle, become very much condensed.

By the opposite extremity, the tendon is inserted into the bones, and usually near their articulations; in a few instances the insertion is placed in an aponeurotic, membranous, or cartilaginous body.

Some of the tendons which are exposed to great friction, are converted into a fibro-cartilaginous and even into an osseous texture; such are those of the peroneus longus and tibialis posticus.*

The tendons are usually secured in their situation by the aponeuroses and tendinous sheaths; and in these places they are covered by synovial bursæ. They also possess bursæ mucosæ where they play against the bones and cartilages, and where they rub against each other. Elsewhere they are surrounded by loose cellular tissue.

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* The small bones found in tendons, have been usually called, after Bichat, *ossa sesamoidea.* Meckel has denominated them, the bones of the tendons.

The force of cohesion and the want of extensibility enable the tendons to perform the only office they are destined to fulfil, viz. that of transmitting to the bones the action of the muscles.

CHAPTER EIGHTH.

OF THE FIBRO-CARTILAGINOUS SYSTEM.

The characters of the different parts which compose this system, are intermediate to those of the two preceding systems; and in consequence of this circumstance, some anatomists have described them as cartilages, whilst others have considered them as ligaments. Many of them appear to be modifications only of the latter organs, and therefore in the table of the solids* I have included them under the general denomination of the fibrous tissue.

It is evident, that Galen had noticed some of these bodies, which he called *neuro-chondroid ligaments*. Vesalius also regarded them as ligaments. On the contrary, Haase described them as cartilages, and divided them into the ligamentous cartilages, *cartilagines ligamentosæ*, and the mixed cartilages, *cartilagines mixtæ*.

The fibro-cartilages were subdivided by Bichat into three classes:—1st. The *membranous*, including those of the ear, the nose, the eyelids, the wind-pipe, the bronchi, &c. 2d. The *articular*, which are either free on both their surfaces, as in the articulation of the knee, of the lower jaw, &c.; or intimately attached on both sides, as those placed between the bodies of the vertebræ. 3d. The fibro-cartilages of the tendinous sheaths, which are met with in the places where tendons rub against the periosteum; for example, the tendons behind the inner ankle.

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* See p. 70.

In the more recent works of Beclard and Meckel it is objected that the organs of the first class belong to the proper cartilages, and ought, therefore, to be omitted; and that it is necessary to add the ligamento-cartilaginous bodies, which are found around some of the enarthrodial joints. Beclard also includes, in the system we are now considering, certain fibro-cartilages in which some of the bones, as the patella, are formed. It must be admitted, that several of these alterations are judicious; but with respect to the fibro-cartilages of the ears, nostrils, &c. I believe their peculiarities are sufficiently marked, to distinguish them from the true cartilages.

The fibro-cartilaginous organs may be referred to two classes, the temporary and the permanent. Those of the first order, which are called the fibro-cartilages of ossification, pass regularly and at determined periods, into the osseous state. They are met with in the substance of tendons and ligaments; they are purely fibrous in the principle, but afterwards become fibro-cartilaginous, and ultimately osseous. The patella and ossa sesamoidea are developed in this manner. Bodies of a similar nature are constantly formed in tendons which rub against bones, *ex. gr.* the gemellus against the condyles of the femur, and the peroneus longus against the os cuboides; they are also contained in certain ligaments, as in the stylo-hyoid and thyro-hyoid.

The permanent fibro-cartilages require to be subdivided into three classes:—

1. Those which have more or less the form of plates or rings. 2. Those of the articulations. 3. Those of the tendinous sheaths.

I. The first class comprehends the fibro-cartilages of the ear, nose, and eyelids; the median fibro-cartilage of the tongue; the epiglottis and the fibro-cartilages of the larynx, trachea, and bronchi. Although these bodies exhibit variations in their density, so that some of them, as those of the larynx and septum narium, are firmer than those of the auricle and alæ nasi, yet all of them are more flexible, less fragile, and more tenacious than true cartilage. The solidity and elasticity which they possess, enable them to maintain the shape and cavity of the canals and other parts which they assist in forming. The majority of them are closely covered by a dense membrane, called perichondrium, which is similar to the investing structure of cartilage; and several amongst them are lined by the mucous membrane. Some of the fibro-cartilages of this class are intimately joined to the neighbouring bones; as, for example, those of the nose and of the external auditory canal; others, on the contrary, are only attached by membranes and muscles, as those of the eyelids and of the larynx. The latter organ is also distinguished by the moveable and perfect articulations, which are formed between its component parts; and farther, by the very sudden development of those parts at the time of puberty.

II. The *articular fibro-cartilages* are of three kinds: *a*. Those which have two free surfaces, usually called the inter-articular cartilages. They are placed in joints, which are exposed to great friction, or to severe shocks; as in the joint of the knee, in that between the ulna and carpus, in the temporo-maxillary, sterno-clavicular, and sometimes in the scapulo-clavicular articulations. Each of these bodies is covered on both surfaces, by the synovial membrane, and the borders are united by a fibrous texture to the ligaments, or to the articular cartilages. They are very elastic, and in most instances they are also moveable, and being thus enabled to change their situation according to the motions of the joint, they powerfully assist in diminishing the concussion that would otherwise be experienced. *b.* The fibro-cartilages placed around the cotyloid and glenoid cavities, which are composed of circular fibres; they are covered on the inner side by the synovial membrane, and on the outer by the fibres of the capsule. They deepen the sockets of the above joints, and so increase their strength; whilst, in consequence of their flexibility and elasticity, they do not so much restrict motion, as if their place had been supplied by an unyielding osseous margin. *c.* The fibro-cartilaginous substance which is placed in the immovable and mixed articulations. It is met with in the sutures of the head, in the pubic and sacro-iliac symphyses, and between the bodies of the vertebræ. This elastic matter adheres firmly to the bones between which it is placed; and on the outer surface it is covered either by the pericranium or by strong ligaments.

III. The *fibro-cartilages of the tendinous sheaths* are formed where tendons play against bones, in consequence of the periosteum being condensed by the continual friction; and also in those places where tendons rub against ligaments. *Ex. gr.* The tibialis posticus against the calcaneo-scaphoid ligament. These structures adhere by one of their surfaces to the bones, and on the other they are covered by synovial membrane.*

The fibro-cartilages are composed of an intermixture of cartilaginous and fibrous substances. These materials form, in different proportions, alternate layers, which are readily distinguished from each other. This disposition is particularly evident in the inter-vertebral fibro-cartilages; where the fibrous portion which preponderates, is arranged in white elastic and concentric layers, and between them the cartilaginous matter is placed; towards the centre there is a whitish pulp, destitute of fibres, and which is apparently *sui generis.* In the inter-articular fibro-cartilages, and in those of the tendinous sheaths, the quantity of cartilage exceeds that of the ligamentous fibres, so that the latter are perceived with difficulty. In other respects the organization of this system does not sensibly differ from that of the cartilages or of the fibrous organs.

The chemical properties of these bodies have not been much attended to; but they appear to be intermediate to those of the two preceding systems. Their physical properties resemble those of the ligaments and cartilages. Their tenacity or force of cohesion is very great, and in some instances it even surpasses that of the bones. They are highly elastic, and thus return promptly on themselves when they have yielded either to extension or to pressure. The vital properties are very obscure.

The permanent fibro-cartilages accomplish several uses. Some of them, as those of the ear, nose, larynx, &c., assist in the formation of very important organs; others give strength and elasticity to the joints in which they are placed; and lastly, there are several that perform the double office of ligament and cartilage, by strongly binding together certain bones, and, in virtue of their elastic property, by adding to the security of their articulations. The temporary fibro-cartilages serve as the mould or type of the bones, whose place they supply.

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* The fibrous tissue is always changed into the above substance, when it is exposed to great friction; for example, the transverse ligament of the atlas is thus altered by the rubbing of the processus dentatus.

In the beginning of life these bodies are soft, and, according to Meckel, they have then a greater resemblance to cartilage, than at a later period. Most of them in the first instance assume the fibrous form, but some pass at once from the gelatinous condition to their perfect state. The fibro-cartilages, with the exception of those of the larynx and the rings of the trachea, are rarely ossified in the advance of life.

CHAPTER NINTH.

OF THE OSSEOUS SYSTEM.

The osseous system consists of those hard parts of the animal frame which are called *bones*. They constitute in man and in all vertebrated animals, an internal skeleton, which determines the form and size of the body; they also give support to the soft parts, and receiving the attachment of the various muscles, they form with these the organs of motion. The invertebrated animals have no internal skeleton, although many of them possess a hard calcareous envelope, which is usually called their external skeleton; but this structure bears more resemblance to the epidermis than to the osseous system of the vertebrata, for, like the epidermis, it is capable of being changed and renovated whenever occasion renders it necessary. Thus the lobster loses its shell every year, when the body has so much increased in size as to become too large for its former covering. In the vertebrated animals, on the contrary, the bones, in virtue of their organization, are spontaneously developed, and by a process of growth similar to that of the soft parts, they gradually enlarge, and attain their full perfection at the same time that the body reaches its maturity.

There is no part of the animal economy that presents a more striking illustration of the adaptation of parts to their particular uses, than the osseous system.

This is apparent in the skeletons of various animals, which are constructed with a reference to their peculiar mode of existence. In birds, for example, the principal bones are pierced by openings which, communicating with the lungs, admit air into their interior, and in this manner add to their dimensions and strength, without increasing their weight.

The spermaceti whale, *physeter macrocephalus*, affords another instance of the great perfection of the skeleton. This inhabitant of the deep, differing in this respect from other fishes, breathes by means of lungs; so that the animal is compelled to rise, from time to time, to the surface, in order to respire the atmospheric air. Now to facilitate this ascent, the osseous cavities of the head are filled with spermaceti, a fluid specifically lighter than water, and consequently well calculated to render the head buoyant and to keep the blow-holes above the level of the sea.*

If we extend our examination to the individual parts of the skeleton, we shall be struck with the same excellence and the same design pervading the form and arrangement of the several bones. Where every thing is so perfect, it is difficult to make a selection; but what can be more admirable than the construction of the skull—of that wonderful piece of mechanism, which is provided for the reception of the brain? It possesses the globular form, which is, of all others, that best adapted to resist external violence; its various bones are fitted to each other with the nicest exactness, and with an evident relation to the great principles of architecture; and, lastly, to secure, in the most efficient manner, the safety of the brain, it is observed, that the cranium is strengthened in those parts which are exposed to injury, by the accumulation of osseous matter, and by the provision of resisting spines and tubercles. The vertebral column, containing as it does a most important part of the nervous system, and constituting at the same time the common centre of the movements of the body, might be adduced as another example of the infinite wisdom displayed in the formation of our corporeal frame.

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* Bell's Anatomy, vol. i. p. 11.

I shall have occasion, in another part of this chapter, to allude to the mechanism displayed in the articulations of the upper and lower extremities. I shall, therefore, for the present, quit this interesting branch of anatomy, which must always excite, in a well regulated mind, a powerful feeling of admiration and reverence.

In order to facilitate the study of the osseous system, I shall divide this chapter into two parts: in the first part I shall consider the various points which are connected with the description of the bones; and in the second part, the process of ossification, or the growth of bone, will be investigated.

PART FIRST.

SECTION I.

NUMBER AND CLASSIFICATION OF THE BONES.

THE human skeleton is composed of a great number of bones; but in consequence of the irregularity which frequently exists in the smaller ones, it is difficult to make an exact calculation. The number is also modified by the age of the person, a circumstance which is owing to the imperfect state of the organs in the commencement of life, when many of the bones are divided, into several pieces; and to the changes which occur in old age, at which period a few of the bones that were separate and distinct in the adult, are consolidated together.

The bones of the adult have been generally estimated at about 260,* but according to Meckel, they amount only to 253. The following is, I believe, the most accurate enumeration. The head contains 62 bones, viz. 8 of the cranium; 14 of the face; 8 of the ear, and 32 teeth. The trunk contains 54, viz. 24 moveable vertebræ; 4 bones of the pelvis; 24 ribs, and a sternum belonging to the chest; and one os hyoides placed in the neck. The upper extremities contain 70 bones, viz. 4 of the shoulders; 2 of the upper arms;

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* Soemmering, Boyer, Monro.

4 of the fore arms; 60 of the hands—16 of the carpus, 8 of the metacarpus, 30 phalanges, and 6 ossa sesamoidea. The lower extremities contain 66, viz. 2 of the thighs; 6 of the legs; and 58 of the feet—14 of the tarsus, 10 of the metatarsus, 28 phalanges, and 6 sesamoid bones.

62	of the head,
54	— trunk,
70	— upper extremity,
66	— lower extremity.
252	Total of the body.

The form of the osseous system is strictly symmetrical, whether we speak of those bones which are single, or of those which are double. The former are placed on the median line, and in all of them it is seen that the lateral parts exactly correspond; such are the frontal, occipital, sphenoid, æthmoid, vomer, inferior maxillary, and hyoid bones; also the vertebræ, the sacrum, the coccyx, and the sternum. Those which are double, are placed in pairs on the sides of the median line, and are similar to each other. The exceptions to the symmetrical arrangement are very few and unimportant.

The figure of the different bones is so irregular, that some anatomists have objected to their being arranged in any other classes than those of the head, trunk, and extremities. Although we must condemn many of those arbitrary and absurd divisions which have been introduced into anatomy, yet we may derive great advantage from a scientific classification of the complicated organs of our frame, when it is founded with a reference to structure and function. The bones are divided, according to the best authorities, into four classes. 1. The long bones. 2. The broad bones. 3. The short or thick bones. 4. The mixed or irregular bones. The organs comprised in this arrangement not only differ from each other in their external form, but also in the more essential particulars of their mode of development, growth, structure, and uses.

Those of the first class, *ossa longa vel cylindrica*, are distinguished by their length, which considerably exceeds their other dimensions. Each of these bones is divided into a body or middle part, and two extremities. The body, *diaphysis*, approaches more or less to a triangular form, but in some instances it is nearly cylindrical; it is usually contracted, especially towards its centre, and also curved. The extremities are enlarged, in order to give security to the various articulations, and to afford an extended surface for the attachment of the principal muscles of the limb; their form is various, according to their uses. The long bones are adapted to the purposes of motion, both partial and general; and in the lower limbs also to the support of the body.

The broad bones, *ossa lata*, are nearly as broad as they are long; but their thickness is inconsiderable. Most of them are arched, by means of which they are adapted to their office, viz. that of forming cavities for the reception and protection of the soft parts; the most perfect specimen of this formation is the cranium. The edges of these bones are generally rather thickened, and frequently serrated.

The short or thick bones, *ossa crassa*, have their three dimensions nearly equal. Their form is usually rounded, cuneiform, or cuboid; they are placed in those parts of the body where strength and motion are combined, as in the carpus and tarsus.

The mixed or irregular bones, *ossa mixta*, are so named because they partake of the characters of the preceding classes, especially of the two last. The sphenoid, temporal, and occipital bones, together with the vertebræ and pelvic bones, belong to this class.

SECTION II.

ARTICULATIONS OF THE BONES.

THE different parts of the osseous system are connected with each other, either directly or indirectly, so as to constitute the skeleton. The junction of any two bones, whatever may be its form or character, is distinguished by the name of *articulation*. The mechanism of this part of the animal fabric is no less interesting to the physiologist on account of its perfection, than it is important to the surgeon in consequence of its connexion with dislocation and fracture. I must, however, confine the few remarks which I shall offer on this subject, to the physiological arrangement of the bones in the superior and inferior extremities.

The upper or pectoral extremity of man is obviously constructed to permit extensive motion. This is greatly facilitated by the lateral projection of the shoulder, which enables us to move the arm freely, especially forwards and laterally, without disturbing the position of the body.* The elbow joint admits of considerable motion; but in consequence of the hinge-like form of it, the fore arm and hand can only be carried forwards and backwards; with this exception, that as the pulley of the inner condyle is directed obliquely towards the body, the fore arm when it is bent, is, together with the hand, necessarily carried towards the chest. The hand in consequence of possessing very numerous and complicated joints, is enabled to produce those numerous and accurate movements which are daily and hourly performed in the ever varying occupations of life. The form of these articulations and of the bones which they unite, together with the lateral projection and size of the thumb, and the inequality in the length of the fingers, evidently fit the hand for grasping and examining surrounding objects, and thus render it a most perfect organ of prehension and of touch.

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* The reader is referred for an interesting account of the mechanical construction of the skeleton, to Mr. Abernethy's Physiological Lectures, Nos. 2 and 3.

The preceding observations shew that the superior extremity and its individual parts are destined by nature to be moved forwards in advance of, or towards the body. This direction corresponds with the situation of the organs of the senses, of speech, and of mastication, with the functions and defence of which, the motions of the upper limb are so immediately connected.

The construction of the inferior or pelvic extremity is as perfect as that of the superior, although it is modified according to its uses. It is provided for the support of the body, and for its various progressive movements; this two-fold object is accomplished by the admirable combination of mobility and strength, which are so apparent in the bones and joints of the lower limb. The hip presents the most complete ball and socket joint in the skeleton; by its depth it securely transmits the superincumbent weight to the os femoris, and at the same time it admits of that degree and variety of motion which are required for the progression of the body. The broad surfaces, which are so remarkable in the articulation of the knee, are obviously adapted, when the limb is extended, for the reception of the weight that is transmitted through the shaft and condyles of the femur; whilst in the flexed position, a lateral motion is permitted in the knee, which is useful in the direction of our steps. In the last place, we must notice the mode of connexion between the leg and the foot. The former is received on a strong but elastic arch, which is described by the bones and joints of the latter; the weight thus received, is diffused in the numerous joints of the tarsus and metatarsus, and is ultimately transmitted to the heel behind, and to the heads of the metatarsal bones on the fore part; but as the balls of the great and little toes are particularly strong and prominent, the pressure anteriorly is principally borne by them, so that the foot in fact rests on a tripod.

The lower extremities thus form powerful columns, on which the trunk is safely supported. In the erect and stationary posture, the bones are firmly knitted together, the knee being then extended, and the foot forming a right angle with the leg, so that the limb may be considered as constituting a pillar, which is placed nearly perpendicularly beneath the pelvis. During progression, the body is alternately balanced on the lower limbs, and so perfect is the adjustment of these and of the other parts of the frame, that the incumbent weight is poised and supported with a certainty and rapidity which are truly astonishing.

The articulations of the skeleton being subservient to the different movements of the body, must necessarily vary in their form and character, according to the kind of motion which they permit. Several writers have arranged them in classes, but most of these divisions are erroneous, or imperfect; it must, indeed, be confessed, that it is almost impossible to contrive any classification, which shall be entirely free from objection. In my lectures I have been in the habit of recommending the classification which was suggested by the celebrated Monro.* But there is another, and I believe a more useful arrangement, which is founded solely with a reference to the mobility or immobility of the joints, and to the form of the articulating surfaces. According to this mode of procedure, the articulations are divided into three classes:—A. The immovable. B. The moveable. C. The mixed.

A. The first species of articulation, termed *synarthrosis,* is met with in the head and pelvis, where strong and flat bones are united to form cavities which are provided for the reception and protection of important organs. In this class, the bones which are kept continuous with each other by an intervening substance, are nearly immovable; it admits of four subdivisions:—1. *Sutura.* 2. *Gomphosis.* 3. *Schindylesis.* 4. *Symphysis.*

1. The suture or seam is the connexion which exists, with a few exceptions, between the cranial and facial bones; it is formed by numerous eminences and depressions, which mutually receive each other. This species of articulation presents two varieties; in the first, the small projections, resembling the teeth of a saw, produce the *sutura serrata,* or the true suture, of which there are

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* Anat. of the Bones. Seventh edition, p. 38.

examples in the union of the frontal, parietal, and occipital bones. Some writers have described a *sutura dentata* and *harmonia*, which are only slight modifications of the serrated suture. In the second variety the bones are bevelled on their edges, giving rise to the squamous or false suture; this is seen in the junction of the os temporis with the os parietale.

2. Gomphosis is that connexion which resembles a nail driven into a board; it is exemplified by the manner in which the teeth are secured in their sockets.

3. Schindylesis is the union by furrowing, in which the plate of one bone is received into the groove of another, as the nasal lamella of the os æthmoides and the fissure of the vomer.

4. Symphysis; this is often classed with the moveable or mixed articulations, but it seems to be more correct to enumerate it with the immovable joints. We have instances of it in the pubic and sacro-iliac symphyses, which may be regarded as motionless, for the only motion they permit, results from the yielding of the elastic substance which is placed within them.

B. The moveable articulations, *diarthrosis*, are those in which the bones, being connected by ligaments, are merely contiguous with each other, but not continuous. This kind of articulation, which is much more important than any of the others, is met with very commonly in the skeleton. It exists between the bones of the limbs, either where they are united to each other, or to the trunk; in the junction of the lower jaw and the cranium; between the skull and vertebral column; between the articulating processes of the vertebræ; lastly, in the union of the ribs with the spine, and of the ribs with the sternum. The articulating surfaces are mutually adapted to each other, in most instances one being concave and the other convex; but there are modifications in their configuration, which may be reduced to the three following varieties:—1. *Enarthrosis.* 2. *Arthrodia.* 3. *Ginglymus.*

1. Enarthrosis, or the ball and socket joint, is that in which the head or rounded process of one bone is received into the cavity of another; it is better calculated for extensive motion than any other articulation. There are examples of it in the hip and shoulder joints.

2. Arthrodia, or the connexion by flat surfaces, is exemplified in the articulations of the tarsus and carpus; it is frequently only a slight modification of the enarthrosis.

3. Ginglymus, or the hinge joint, is more complicated than either of the former; there are two varieties in this species of articulation:—*a.* The angular ginglymus, or hinge, is that in which one bone has a pulley-like surface, called *trochlea,* into which another bone is received; as in the elbow and knee joints. *b.* The lateral or rotatory ginglymus is formed by the cavity of one bone receiving the convex process of another. It admits of a subdivision into double and single; it is double when one bone turns on another in two distinct places; *ex. gr.* the radius rolling on the ulna; it is single, when the motion is performed at a single point; *ex. gr.* the articulation of the atlas with the odontoid process.

The effect of the preceding varieties in the form and disposition of the articular surfaces, is to modify in a very important manner the motion which is permitted in the diarthrodial joints. Bichat, in his valuable work,* refers all the various movements of the body to four species: 1. The motions of angular opposition. 2. Of circumduction. 3. Of rotation. 4. Of gliding.

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* Anat. Gen. t. ii. p. 174.

1. The motion of opposition or angular movement is that in which the long bones describe between one another, angles varying in size according to the degree of separation or of approximation. In some joints, as in the knee and elbow, the motion is confined to flexion and extension; in others, as in the hip, in the shoulder, and thumb, it is more vague or general, consisting of flexion, extension, abduction, and adduction, and of the various motions which are intermediate to them. 2. Circumduction is the movement in which the bone describes the circumference of a cone, the apex of which is placed in the upper end of the bone, and the base in its distal extremity. This motion is produced by a combination of flexion, adduction, extension, and abduction; it is most extensively exercised in the joint of the shoulder. 3. Rotation is altogether different from circumduction. In the latter, the bone changes its situation as it moves from one point to another; in the former, it remains always in the same place, merely turning on its axis. This species of motion is observed in its greatest development in the ilio-femoral articulation. 4. The contiguous surfaces of all the diarthrodial articulations, enjoy a *gliding* movement on each other; and there are some joints, as those of the carpus and tarsus, which have no other motion.

C. The mixed form of articulation, *amphi-arthrosis*, resembles the synarthrosis in having the bones united by an intervening substance, and the diarthrosis by admitting sensible movements.* The fibro-cartilaginous connexions of the bodies of the vertebræ are the only proper examples of this mode of articulation. Many anatomists also include the junctions of the bones of the pelvis, and of the first and second portions of the sternum; but these articulations ought to be classed with the immovable ones. The amphi-arthrosis appears to form a gradation between the synarthrosis and the diarthrosis.

TABLE OF THE ARTICULATIONS.

- Articulations
  - Synarthrosis or Immovable Articulation
    - Sutura
      - Serrata
        - Dentata
        - Harmonia
      - Squamosa
    - Gomphosis
    - Schindylesis
    - Symphysis
  - Diarthrosis or moveable Articulation
    - Enarthrosis
    - Arthrodia
    - Ginglymus
      - Angular
      - Lateral
        - Double
        - Single
  - Amphi-arthrosis or Mixed Articulation

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* Beclard, Anat. Gen. p. 551.

SECTION III.

PROCESSES AND CAVITIES.

THE external surfaces of the bones present various projections and depressions, which, in many instances, cause a very irregular appearance.

The projections are distinguished by the terms of *apophyses* and *epiphyses*. The latter exist only in the earlier periods of life, when the ends of the bones, and also the majority of their processes, are separated from the body by a layer of cartilage; they will therefore be considered with the process of ossification.

The apophyses or processes are divided into the articular and the non-articular. The first are named according to their forms; they are called heads when they approach more or less to the hemispherical shape; if they are flattened and elongated they are termed condyles; and when they have the form of teeth, they are called serræ or dentations.

The non-articular processes are eminences which vary very much in their form and size; some of them project considerably from the surface of the bones, and are named, from their supposed resemblance to certain bodies, from their relative position, or from their uses. Thus there are processes which are called, coronoid, mastoid, styloid, coracoid, spinous, odontoid, transverse, orbitary, trochanteric, &c.*

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* Monro, Anat. of the Bones, p. 24. Cloquet's Anat., translated by Dr. Knox, p. 12.—The student will find this a very faithful translation of one of the most modern and best treatises on descriptive anatomy, which has appeared in France, or, perhaps, in any other country.

Those processes which are short, thick, and rough, are called tuberosities.

Lastly, there are others which project but little from the bones, and are distinguished by their narrowness and length ; they are named lines, ridges, and spines.

The principal uses of the apophyses are to render the joints firm and secure, and to afford points for the attachment of muscles ; those which are prominent also diminish the parallelism of the muscle with the axis of the bone, and by enlarging the angle at which the former is inserted into the latter, they increase the muscular power.

The cavities of the bones are, like the projections, divided into the articular and the non-articular. The articular cavities are of various depths and forms ; those which are deep with large brims, are named cotyloid, and those which are superficial are called glenoid cavities. When the depression has the form of a pulley, it is termed trochlea ; and, lastly, the cavities which are conical, are called alveoli.

The non-articular cavities are very numerous, as they are met with in all parts of the bones. Some of them completely pass through the bones ; others penetrate deeply into their substance ; and several are confined nearly to the surface, and are consequently superficial. Those of the first species are called foramina, or holes, if they pass through a thin bone, and canals or conduits if their passage is of greater extent. It frequently happens that two or more bones are united to form a foramen or canal ; as, for example, the foramen lacerum basis cranii posterius, and canalis palato-maxillaris. These holes and passages are provided for the transmission of soft parts, especially for vessels and nerves.

The cavities which penetrate deeply, but do not pass through, are of two kinds; those of the first class are formed in the substance of the bones, and, having small apertures, they are called sinuses; or, if they are divided into several spaces, they are termed cells; they are all lined with mucous membrane, and are filled with air. The cavities of the second class are formed for the transmission of vessels, which are provided for the nourishment of the bones. They are of various sizes, and may be referred to three varieties. 1. In the long bones they form canals, which commence towards the middle of the shaft, by an opening which is called the medullary foramen; they slant obliquely into the interior, or cancellated structure; the large irregular bones, as the ossa innominata, possess similar canals. 2. The ends of the long, and the surface of the short bones, have numerous openings, which lead to their internal spongy texture; we may judge of their number from the fact, that Bichat counted one hundred and forty on the inferior extremity of the femur, and fifty on the os calcis. 3. The third species of nutritious passages consists of a great number of minute pores, which can be seen with the naked eye on the surface of the compact structure; the blood-vessels which enter these openings, and also those of the second class, are derived from the periosteum; but the arteries of the medullary foramina are distinct from the fibrous membrane, having their origin in some of the large neighbouring vessels.

The superficial cavities are numerous, and of diverse forms. Those which are larger at their orifice than at their bottom, are called fossæ; they are intended for the reception of soft parts, as the digastric and lacrymal depressions; some are formed for vessels and nerves, these are termed furrows, grooves, &c.; others for tendons, ligaments, &c.

The bones are strongly marked in the male skeleton, the various processes being large and developed, and the cavities distinct and well defined; this strength of the bones corresponds with the fulness and power of the muscular system, with which they are so inseparably connected. The skeleton of the female, on the contrary, is more delicately framed; the bones are small and lightly made; the processes are but little prominent, so that there is an absence of that asperity and inequality which are so strongly characteristic of the skeleton of the male. There are also differences which relate to the important function of generation. Thus the chest is short, the lumbar portion of the spine is elongated, and the pelvis especially, is very capacious; all these modifications in the dimensions of the trunk, are evidently intended to increase the size of those cavities which receive the impregnated womb.

SECTION IV.

MECHANICAL TEXTURE OF BONE.

NOTWITHSTANDING the attention of anatomists has been for a long period directed to the investigation of the texture of bone, there is at the present day considerable difference of opinion on this subject. Malpighi is usually considered as the first who threw any light on the intimate structure of these organs. He discovered that their basis consists of an animal matter, which has been proved, by recent experiments, to be cellular tissue very much condensed. In the cells and areolæ of this substance, a quantity of earthy matter is lodged, which was noticed by Herissant nearly one hundred years ago, although the chemical nature of it was but little understood until about forty years since.

In order to examine the osseous tissue, it is necessary, on account of its extreme hardness, to prepare the bone by steeping it for a sufficient time in diluted muriatic or other acid,* by which means the earthy part is removed from the bone, which thus becomes soft and flexible; it still retains in a perfect manner its form and volume, although the weight is diminished in proportion to the matter it has lost. The animal substance obtained by this process, has the character of cartilage, and is capable of being reduced by continued maceration, into common cellular tissue. There is another method of displaying the internal structure of bone; viz. by calcination, which destroys the animal matter, and leaves an earthy substance, having the size, form, and a great part of the weight, of the original organ.

When a bone is minutely examined in its natural state, or after either of these modes of preparation, it is apparently composed of a great number of fibres, which are variously disposed, and in many places there is an appearance of a laminated structure.† These fibres by their irregular crossing, produce numerous cells, whose size and distinctness vary in the compact and spongy textures. The existence of the laminated structure has been denied by Bichat, who thinks that anatomists have been deceived by the manner in which they prepared the bone for examination. A similar opinion is also entertained by Howship and Scarpa; they contend that the ultimate texture of bone is reticulated; and that the phosphate of lime is deposited in the interstices which are thus formed. Dr. Bostock, whose sentiments always demand attention in consequence of the cautious manner in which he draws his conclusions, admits the existence of plates in the adult bone. I am myself, however, inclined to agree with the former high authorities; because, if the animal substance which forms the mould of the internal parts of the bone, be carefully examined after a prolonged maceration, no real laminæ can be satisfactorily detected.

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* Dr. Gordon prefers the muriatic acid. Anat. 253.

† Some anatomists, especially Gagliardi, conceived that there were osseous plates, which were joined to each other by a number of small processes resembling nails of different shapes.

The size of the fibres is liable to great variation; some of them are so delicate, that the least touch breaks them, whilst others have a much greater firmness. In the long bones, the fibres pass more or less in a longitudinal direction; in the broad ones they often distinctly radiate, a disposition which is very evident in the parietal and frontal bones, particularly in the fœtus; in the short bones no regular arrangement can be seen, as the fibres run in all directions, according to the form of the individual bones.

The osseous matter exhibits other and more striking diversities in its appearance, which are displayed by making sections of bones belonging to different classes, and of different portions of the same bone. These varieties, which principally depend on the inequality of density observed in the interior, have been reduced to two, which are described by anatomists as the compact and the spongy substances. The former is distinguished by its solidity, which is so great, that no interstices can be perceived in it by the naked eye; there are, however, minute canals, which are visible with the aid of the microscope. These passages, which were noticed by the older writers,* have been recently examined by Mr. Howship,† from whose careful investigations we learn that their size is various, being larger towards the medullary cavity than towards the exterior, where they become uniformly smaller; their mean diameter is about $\frac{1}{200}$ part of an inch. They have numerous lateral communications with the medullary cavity, and also with the external surface; they appear to be lined with a delicate membrane, which conveys the blood-vessels destined to secrete the medullary matter with which the canals are filled; this matter has the consistence of spermaceti, and is of an opake and white colour.

The spongy substance exhibits varieties in its appearance, which are so considerable, that many authors have described them as distinct textures, under the names of the *reticular*, *alveolar*, *cancellated*, &c.; they are, however, merely modifications of one structure. This consists of numerous fibres crossing each other in different directions, and thus intercepting spaces between them of various forms and sizes; in the middle of the cylindrical bone they are large, but few in number, whilst at its extremities they are numerous and small.

Notwithstanding the apparent distinctness of the compact and spongy textures, they are in reality but one and the same substance, which presents different appearances according to the quantity of the phosphate of lime that it contains. These two structures are met with in various proportions in every bone of the body, the compact forming the external part or wall, and the spongy the internal portion.

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* Havers, Osteologia Nova. Monro, Anat. of the Bones.

† Medic. and Chir. Trans. vol. vii.

The body of the cylindrical bone is formed principally of the compact substance, which decreases in its density towards the interior, and at length ends in an expanded tissue, which being formed of large cells, is frequently distinguished by the name of cancellated tissue, or lattice-work; in the centre, the osseous fibres nearly or entirely terminate, so that a hollow may be seen in the macerated bone, which is occupied in the living subject by numerous cells formed by the medullary membrane. The ends of the long bones are greatly enlarged, and are composed principally of the spongy substance which is covered by a thin crust of the compact texture.

The peculiar disposition of the ossific matter in these bones, is admirably adapted to the purposes for which they are destined. The middle is the part most exposed to external violence; now, in order to afford the necessary resistance, the compact substance is accumulated in considerable quantity, and as it is arranged around a centre which is nearly hollow, the circumference of the bone is augmented without any addition being made to its weight. The advantage of this arrangement is evident; for it is a law of mechanics, that the resistance of a cylindrical body to a force applied transversely, is increased in proportion to its diameter; so that the same number of fibres placed, as it were, round the circumference of a circle, produce a stronger bone than if they had been all united in the centre, and the diameter of it had been proportionally diminished.* The extremities of the long bones are also excellently contrived, for in them the osseous matter is expanded so as to enlarge their diameter, by which means a greater space is afforded for the attachment of the numerous tendons, at the same time that the joints are rendered strong and secure.

In the short bones, the spongy substance is accumulated; and for this reason the os calcis, and others of the same class, possess a porous character; they are covered on the exterior by a crust of denser substance. The compact substance of the broad bones is of considerable thickness; it forms two layers, of which the internal one in the cranium being denser than the outer one, is distinguished by the name of *tabula vitrea*. The spongy tissue, which is similar to that of the ends of the long bones, is often almost entirely deficient towards the centre, where the bones are semi-transparent; in the head, it is called the diplöe.

SECTION V.

ORGANIZATION OF BONE.

THE bones differ so entirely in their appearance and durability from all the other organs of the animal frame, that it is difficult to conceive of their structure being essentially the same as that of the soft parts. The principal peculiarity in their composition is owing to the large quantity of calcareous earth which they contain. This substance enables them to resist for a lengthened period the influence of chemical agents, so that they remain for ages the memorials of the dead, the evidence of a former race of men, or of animals which have ceased to exist since the last great revolution of our globe; the proofs of such changes in nature, as we cannot trace but by these uncertain marks.[*] Minute anatomy reveals the complicated organization of the bones; shews their membranes, their blood-vessels, and even their nerves; and thus explains how these organs may be affected with the same diseases as the soft parts, and how, like them, they may, by their own unaided powers, be restored to health.

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* Bostock, Elem. Sys. of Phy. vol. i. p. 106. Bichat, t. ii. p. 142.

In consequence of the great vascularity of the osseous system, the arteries in the large bones are easily injected, and after the earthy matter has been removed by the action of diluted acid, they may be traced into the internal substance. There are in general two distinct orders of sanguiferous vessels; one set being furnished by the periosteum, and the other by the artery which passes through the medullary canal. The arteries of the first set, which are very small and numerous, penetrate by the openings placed on the external surface of all the bones;[†] they are regarded by some anatomists as the only proper nutritious vessels of the osseous texture. The arteries of the second class pass through the medullary foramina and canals, and on reaching the interior, each of them divides into two branches, which in the long bones immediately diverge, and then run in a parallel direction with the shaft; they are distributed in an especial manner to the medullary membrane, where they ramify and secrete the marrow; and eventually, having passed through the cancellated texture into the compact substance, they communicate with the arteries of the first class. This anastomosis is free in proportion to the youth of the individual; a circumstance which explains the ready union of the periosteum when it has been detached in a young person; and also how it happens that in those cases where the periosteum does not adhere, the bone, provided it has not itself been injured, does not die, but throws up granulations from its surface.

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[*] Bell's Anatomy, vol. i. p. 179. Clift, in Phil. Trans. for 1823, p. 84, *et seq.*

[†] See p. 384.

The medullary arteries are accompanied by veins which exactly correspond with them in size and number; but the arteries derived from the periosteum do not possess corresponding veins. It has, however, been ascertained by M. Dupuytren, that there are proper veins of the osseous tissue, which pass from the interior by openings, in which no arterial ramifications can be perceived, even after the most successful injection; they are composed only of the internal membrane of the venous system, which is folded into numerous valves.*

Lymphatic vessels have not been seen in the interior of the bones, but they may be distinguished on the outer surface of the large ones; their existence, however, cannot be doubted, as we have constantly proofs of their action in caries and necrosis, and also in the rare affection called mollities ossium.

The experiment of feeding an animal on madder, exemplifies, in a striking manner, the activity of arterial deposition, and also of lymphatic absorption. It is well known that, after the use of this substance for a short time, the bones assume a red tinge, in consequence of its colouring matter being secreted from the arteries; now, if the use of the madder be discontinued for some time before the animal is killed, it will be found, on examining the bones, that they have regained their natural colour, a change which could have happened only by the agency of absorption.

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* Propositions sur quelques points d'Anatomie, de Physiologie, et d'Anatomie Pathologique, Paris, 1803.

The nerves which enter the bones accompany the medullary artery; they are very minute, and form, according to Richerand, a plexus around the vessel. Soemmering thought that these nervous filaments were merely destined for the blood-vessels, whilst others contend that they supply the medullary membrane. The existence of nerves in the substance of bone, is, however, generally, and I believe correctly, admitted; the most direct evidence in support of this opinion is deduced from the fact that bones become painful when they are inflamed.

Every bone is covered externally by a dense structure, called the periosteum, and internally it is provided with a delicate production, known by the name of the medullary membrane.

The periosteum has been described in the chapter on the fibrous organs. See page 351.

The *medullary membrane*, or internal periosteum, lines the cells of the spongy substance, and even penetrates into the compact texture. It exists in the four classes of bones, but is most distinct in the long ones. It forms numerous little bags, which are similar to those of the adipose tissue.* The elder Monro, and several modern anatomists, contend that these cells communicate with each other; but it is most probable that no such communication really exists.

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* See p. 134.

The vesicles are generally supported by the osseous fibres, but, in the middle of the long bones, they are not thus protected, because the bony matter is there nearly deficient. The medullary membrane consists of an extremely delicate process of the cellular tissue, which can be demonstrated by sawing a bone and plunging it in an acid, when the membrane is detached in the form of a distinct canal.*

The fluid secreted by the medullary blood-vessels is known by the general name of *marrow;* it is principally contained in the centre of the long bones, but some part is lodged in the spongy substance, where it is often called medullary fluid. The compact tissue also encloses an oily juice, which is probably contained in the longitudinal canals already mentioned; it is, according to some writers, of a thinner consistence than marrow, and has been termed, to distinguish it, *oil of bones.* The late Dr. Gordon denied that there was any oily matter in pure bone; he says, that when it seems to exist in it, it has been derived by transudation, either from the adipose substance without, or from the marrow within. The marrow is formed of the same principles as common fat, only in different proportions, being more fluid and of a yellower tinge. In the bullock the medulla of the long bones consists of, fat, 96; reddish serum, 3; membranes and vessels 1=100.

The marrow does not exist in the fœtus nor in the young subject; although the membrane is seen when the bone is hollowed into a canal by the progress of ossification, but it contains in the beginning merely a viscid and gelatinous fluid. In old age the interior of the bones being hollowed by a progressive absorption of the osseous matter, the marrow accumulates in large quantity.

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* Beclard, Anat. Gen. p. 175.

There is much uncertainty concerning the use of the medullary fluids. The most distinguished authorities of the time of Boerhaave and Haller, thought that the marrow served to render the bones less brittle, and this opinion has even been adopted more lately by Blumenbach and others. But there is no doubt that the flexibility of the bones depends on the animal substance which they contain, and not on the marrow; it is for this reason that the bones of young persons, which have little or none of the latter substance, are more yielding and less fragile than those of old people, in which the marrow is greatly accumulated. The real uses of this fluid are in all probability the same as those of the fat in other parts of the body; but in addition it serves to make the bones lighter in consequence of its low specific gravity.

SECTION VI.

CHEMICAL COMPOSITION.

WE are indebted to modern chemists for a correct knowledge of the composition of bone. It has been already stated that the basis of the osseous structure consists of an animal substance, which was discovered by Malpighi. This has been proved by the investigations of Mr. Hatchett, to possess all the characters of condensed albumen. Before the experiments of this chemist, it was erroneously supposed that the animal matter consisted of jelly, an opinion which is still maintained by some of the most distinguished continental anatomists. The bones of young animals certainly contain a proportion of jelly, but, according to Dr. Bostock, those of the adult will yield but very little of that substance unless the water be applied at an unusually high degree of temperature, as by means of Papin's digester.

The earthy substance has been ascertained to be more compound than the chemists thought, by whom it was first examined. Besides the phosphate of lime, which forms nearly 82 per cent. of the weight of the earth, it contains, according to Berzelius, the fluate and carbonate of lime, with the phosphates of magnesia and soda. Mr. Hatchett also enumerates the sulphate of lime, but this is considered by Berzelius to be simply a product of calcination. Fourcroy and Vauquelin, by a very delicate analysis, detected in bone, iron, manganese, silica, alumina, and phosphate of ammonia.

ANALYSIS OF DRY HUMAN BONES (BERZELIUS).

Cartilage and some gelatine . .	33·3
Phosphate of lime	51·04
Carbonate of lime	11·3
Fluate of lime	2·0
Phosphate of magnesia . . .	1·16
Soda and hydro-chlorate of soda	1·2
	100·00

It has been ascertained, by the experiments of Dr. Davy, that the bones of the head contain more of the earthy substance than those of the extremities; but the greatest differences in the proportion of the constituent principles are those which depend on the age of the individual.* In proceeding with the description of the process of ossification, it will be found that in the embryo, till about the end of the first month, the place of the bones is supplied by a mucous or gelatinous fluid. At birth, and during the first years of life, the organic part is in larger quantity than the inorganic, and consequently the bones being then more flexible, are less apt to break, and when they are fractured they are more speedily consolidated. In youth the two component parts are nearly in equal quantities; in the adult the calcareous earth forms about two-thirds of the osseous substance; whilst in old age, in consequence of its accumulation, it occupies the part which was formerly organized, and thus not only renders the bones more brittle, but also retards, or even altogether prevents their union, when they have been broken.

SECTION VII.

PROPERTIES AND USES.

THE bones are distinguished from all other parts of the body, by their great solidity and durability, which qualities depend on the calcareous substance they contain. Many anatomists speak of their elasticity; but this property is very inconsiderable, or, indeed, entirely deficient, except in the beginning of life. Bones are endowed with a certain degree of extensibility, so that they may yield to a distending force, which is gradually applied; this is seen when tumours of various kinds are formed in the interior of osseous cavities, as in the maxillary sinus, the nostrils, and orbits. After being extended they are capable of contracting themselves, but in a very slight degree.

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* The pars petrosa of an adult contained 33·3 animal matter; 66·7 earth. The parietal bone of an adult, 35·6 animal matter, 64·4 earth. The thigh bone of an adult, 37·5 animal matter, 62·5 earth. Parietal bone of a child fifteen years of age, 41·2 animal matter, 58·8 earth. Thigh bone of the same subject, 53· animal matter, 47· earth. Monro, Outlines of Anat. vol. i. p. 36.

These organs are of a yellowish white colour, the tinge being generally deeper in the advance of age. During life they have a dark reddish brown or purple colour owing to the quantity of blood they contain.

Although the bones do not exhibit any of the striking phenomena which are regarded as the distinctive characteristics of life, we must not therefore conclude that they are deprived of vitality. The observations which have been offered in the preceding pages of this chapter, sufficiently prove that the bones are nourished and renovated like the other parts of the body; and the processes that occur in the various accidents and diseases to which they are liable, still more forcibly demonstrate that they are endowed with the living principle. They are not sensible in their healthy condition, but become so during inflammation, so that they are then extremely painful. It is necessary to distinguish the properties of the internal membrane and of the vessels, from those of the ossific structure which contains them.

The uses of the bones, although of a mechanical nature, are of great importance in the higher classes of animals. They determine the stature and the general form of the body, and give to its individual parts the outline and proportions which their various offices in the economy require. The bones also support and protect the softer materials of the frame; either as in the instance of the limbs, by affording columns against which the muscles, vessels, and nerves are firmly sustained; or by describing cavities in which the organs more immediately necessary to life, are safely enclosed. In the last place, the osseous system constitutes a very important part of the apparatus of motion; not only by serving as fixed points for the attachment of the muscles, but also by forming the principal portion of the several articulations.

PART SECOND.

OF THE FORMATION OF BONE.

THE manner in which the process of ossification is accomplished, has been for a long time the subject of much speculation among physiologists. Nor can this excite our surprise, when we reflect on its importance in health and in the reparation of the effects of accident and disease; in the former state, it affords us an admirable instance of the resources of nature in building up the structure of the body; and in the latter, it exemplifies the restorative powers which are possessed by parts even so lowly organized as the bones. Notwithstanding the numerous experiments and observations which were made by the older anatomists, the most erroneous ideas with respect to the formation of these organs and the production of callous, were prevalent even in the time of Haller. The investigations of modern observers have shewn that the only peculiarity in the growth of bone, is the deposition of a certain quantity of earthy substance in the animal mould which is destined to receive it, and that in other respects, there is no deviation from those general laws, which govern the development of the other parts of the animal body.

SECTION I.

COMMENCEMENT AND TERMINATION OF OSSIFICATION.

DURING the early period of the existence of the embryo, the bones consist of a viscid fluid; they then become soft and gelatinous; afterwards cartilaginous; and lastly, osseous. Some writers think that the animal substance, which in the first instance composes the basis of bone, is mucilaginous; but others contend that it is gelatinous, and as the bodies of young animals always contain a considerable proportion of jelly, I am inclined to concur in this opinion.

It is difficult to define the exact time when ossification commences; according to Beclard, it begins about a month after conception; whilst Meckel says, that this process does not really commence until towards the eighth week, although the cartilages which supply the place of the future bones, of which they have the form, appear at the fourth week. The different bones do not begin to appear at the same time, but in a successive order, which has been minutely detailed by some writers. The long bones, with a few exceptions, are developed before the flat ones, and the latter before the short bones. Thus the clavicle, the ribs, the inferior jaw, and the great bones of the extremities, appear before the os occipitis and the os frontis; and some months before the carpal and tarsal bones, a few of which contain no ossific centre even at the time of birth. It has also been observed, that the bones which are near the centres of the nervous and vascular systems are formed at an early period.

The following is a general scale of the commencement of ossification in the various parts of the skeleton. The process begins at the end of the first month,* in the clavicle, and successively in the inferior maxilla, the femur, the tibia, the humerus, the superior maxilla, and in the bones of the fore arm, in the latter of which it commences towards the thirty-fifth day. The fibula, the scapula, and the palate bones appear towards the fortieth day, and in a few days after ossification begins in the following parts: viz., in the tuberosity of the os occipitis, the os frontis, the arches of the upper vertebræ, the ribs, the great wing of the sphenoid bone, the zygoma, and the phalanges of the fingers. About the same time the earthy substance is deposited in the bodies of the dorsal vertebræ, the ossa nasi, the ossa malarum, the ilium, the metacarpal bones, the phalanges of the toes, the condyles and basilar process of the os occipitis, the squamous portion of the temporal bone, the parietal bone, and the vomer; in all these bones the process begins after the middle of the seventh week. Towards the middle of the ninth week it commences in the body of the sphenoid bone, in the bodies of the upper sacral vertebræ, and in the ring for the membrana tympani. In the middle of the third month, ossification is manifested in the labyrinth, and towards its end in the ischium and internal pterygoid process; and in the middle of the fourth month it is seen in the ossicula auditus. At the middle term of gestation osseous matter is deposited in the pubis, the os calcis, the smallest phalanges of the toes, the lateral parts of the æthmoid bone, and in the ossa spongiosa; and a little later in the first pieces of the sternum. Towards the sixth month, the process commences in the body and odontoid process of the second vertebra, in the lateral parts of the first sacral vertebra, and afterwards in the astragalus; and at the seventh month in the crista galli of the æthmoid bone. Towards the close of the fœtal existence, the earthy substance is deposited in the os cuboides, the first portion of the coccyx, and in the fore part of the ring of the atlas. At the age of one year, the coracoid process begins to be ossified, and the same may be said of the magnum and unciform of the carpus, and of the first cuneiform of the tarsus. The patella is formed in the third year. The second and third ossa cuneiformia and other bones of the tarsus and carpus, are formed successively between the fourth and the twelfth years.

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* Beclard, Anat. Gen. p. 496.

The process of ossification is not simultaneously completed; and it is remarkable that bones which appear very early in the embryo, are not perfected till a late period; thus the condyles of the os femoris, which bone is so precocious in its formation, are not consolidated with the shaft before the age of eighteen or twenty years; whilst many of the short and irregular bones in which the process is more tardy at the commencement, are completed much earlier. The os frontis frequently remains divided into two parts after the other bones are formed, so that the frontal suture does not disappear till the twenty-fifth year, and occasionally it is perceptible in advanced age.

SECTION II.

DIFFERENT MODES OF OSSIFICATION.

IT has been ascertained by the ingenious and laborious researches of several modern physiologists, that the ossific matter is deposited under three different forms: 1. In the soft and gelatinous condition of bone. 2. In the substance of cartilage. 3. Between two membranes. It has been contended by some high authorities that cartilage is a necessary antecedent to bone; but this opinion has been refuted by the experiments of Mr. Howship, who has shewn, that the first rudiments of ossification in the long bones, appear before the evolution of any cartilaginous structure.* These observations have been confirmed by Serres and Beclard, who suppose that in those bones which are first developed, or in those parts of bones in which the process takes place at an early period, the osseous substance is deposited in the fluid form; whilst in those bones which are formed at a remoter period, the cartilaginous or intermediate state which they assume, is rather a provisional condition than a stage of ossification—a temporary structure for the purpose of performing the functions of bone, and not a necessary antecedent to the ossific process.

I shall now proceed to describe the three modes of ossification.

1. In the diaphysis of the long bones and in the centre of the broad ones which are early developed, there is an appearance of osseous matter before any cartilage can be detected; this matter, which is arranged in the form of a short hollow cylinder, is secreted, according to Mr. Howship, from the arteries of the periosteum, and consequently is deposited from without, inwards. It is stated by Beclard that the earthy substance is deposited in a fluid condition and at the same time with the

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* Medical and Chirurg. Trans. vol. vi. p. 264.

animal matter, in the organized tissue which secretes it. Its subsequent solidity is probably owing to the continued deposition of phosphate of lime, and to the absorption of the fluid parts. Dr. Bostock is doubtful if the soft matter in which the osseous cylinder is formed, be not itself the future cartilage, merely in a soft state, united to a large proportion of water.* It is difficult to decide this question; but as there is no sufficient proof to shew that the fluid substance is only cartilage in an imperfect condition, we should not be justified in rejecting Mr. Howship's conclusion.

2. In a rather more advanced age of the embryo, the mode of ossification is changed, in order that it may proceed more speedily. At this period, which is about the eighth week after conception, the temporary cartilages appear, in the centre of which the osseous matter is deposited.

We learn from the observations of Mr. Howship, to whom we are indebted for a minute account of these cartilages, and the changes they experience by the progress of ossification, that when they are first formed they contain several irregular cavities, which are afterwards converted into canals; they are lined by a vascular membrane, and are filled with a considerable quantity of gelatinous matter. These passages gradually decrease in number and size, so that in a child eleven months old there are but few of them; at the age of eleven years the canals are further diminished, and at seventeen years it is with great difficulty that any trace of them can be found.

The cartilage in the beginning contains minute vessels, which carry only a colourless fluid; but as the process advances the arteries are enlarged so as to admit red blood, by which the cartilage is tinged. Several arteries appear, and by their communication produce a vascular plexus, from which particles of the phosphate of lime being deposited, a *centre of ossification* is formed. These particles, when they become first apparent and coherent, constitute an assemblage of very fine and thin fibres, which are moulded into the form of short tubes, and extend according to the length of the bone. The cartilage now grows opaque, yellow, and brittle, and will no longer bend; the small osseous nucleus may be felt, and, when touched with a sharp point, is easily known by its gritty feel. Other centres of ossification are successively formed, always being foretold by the spreading of the arteries, and by the arrival of red blood.[*]

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* Physiology, vol. i. p. 117.

The first point of ossification, which is invariably formed in the interior of the cartilage, and never at its surface, continually increases by the addition of new matter; and in proportion as the earthy phosphate is deposited, the cartilage is removed by the absorbents, till at length, the bone being perfectly formed, it disappears.

These two processes, according to the doctrine of Mr. Hunter,[†] are proceeding at the same time, and mutually assist each other; the secretory vessels bringing supplies to the bone, and the absorbents carrying away the original particles so as to give it a proper form. Although the actions of the arteries and lymphatics correspond in point of time, yet they differ as to the seat of their relative activity, the greater quantity of osseous matter being deposited on the outer surface of the bone, whilst the absorption is carried on at the centre; so that when the external part acquires its proper degree of hardness the interior is either formed into a complete cavity, or is hollowed into an immense number of cells producing the spongy substance that has been described.* As the original cartilage contains no cells, it does not possess any medullary membrane; but after the cavities are produced the internal periosteum is developed.

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[*] Bell's Anatomy, vol. i. p. 184.

[†] Trans. of a Society for the improvement of Med. and Chir. Knowl. vol. ii. p. 281.

3. The third mode of ossification, viz. that between membranes, exhibits peculiarities which are not met with in either of the former processes. The bones of the cranium, which are formed in this manner, begin to appear about the seventh week after conception, at which time the pericranium and dura mater are very vascular. The phosphate of lime is first deposited in minute granules, which are dispersed in unequal masses and without regularity between the membranes; they afterwards coalesce and form fibres, which have a radiated disposition from the centre towards the edges. The intervals between the fibres are filled with a glairy and colourless fluid, which is similar in its sensible qualities to the substance found in the canals of the temporary cartilages. The surfaces of the bones are also covered with a gelatinous and reddish fluid, which contains a great number of the finest capillary arteries variously disposed.†

The short or thick bones are ossified in the same manner as the extremities of the long ones. They are

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[*] See p. 389.

[†] Howship, l. c. p. 280.

preceded in their formation by cartilages, which are at first homogeneous and full; they are then hollowed into cavities and canals similar to those already described, and are at length converted into bone.

The patella and the ossa sesamoidea, are formed in a tissue which is at first fibrous and afterwards cartilaginous. The mixed or irregular bones participate by their formation, as by their external figure and internal structure, in the characters of the three other classes.

The growth of the bones is in most instances accelerated, in consequence of each of them possessing several distinct points of ossification. Many that are placed on the median line are formed by two lateral halves, which are united at a later period; *ex. gr.* the arches of the vertebræ, the frontal, the body of the sphenoid, the occipital, the inferior jaw, and the central pieces of the sternum. It has been discovered by Serres that even in those central parts of the median bones, as the bodies of the vertebræ, and the body of the os hyoides, in which it was formerly thought that ossification began in the middle, and extended to the sides, the process really commences by two lateral points which afterwards coalesce on the median line.*

In some bones there are several primitive points of ossification, which are sooner or later consolidated together; they are met with in the vertebræ, os occipitis, os sphenoides, os temporis, sternum, sacrum, &c.

The most important circumstances connected with this phenomenon of ossification, are observed in the long and in a few of the short bones, which have accessory centres of ossification, called *epiphyses.* The great bones of the thigh, the arm, the leg, and the fore arm, have at least one epiphysis at each end; but the smaller bones, as those of the metacarpus, metatarsus, and fingers, have only one epiphysis, and the same may be said of the clavicle and of the os calcis. The large bones have cartilaginous edges, which have been called by some anatomists their marginal epiphyses; they are very apparent in the scapula and os innominatum. The epiphyses, which begin to be formed about fifteen days before birth, do not disappear till the eighteenth or twentieth year, and sometimes not till the twenty-fifth year. They are separated from the shaft by a layer of cartilage, which is of considerable thickness in the beginning, but as the process approaches its completion, the intervening substance becomes very thin, and is at length entirely removed.* The large processes, as the trochanter, are likewise separated from the shaft by a portion of cartilage; these detached processes have been called by some writers, *apophyses.*

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* Sur les Lois de l'Osteogenie. The above is a very remarkable instance of the eccentric mode of formation already alluded to at p. 77.

The growth of bones takes place in the direction of their height and of their circumference, so that the new substance is not only added at their extremities, but also penetrates into the mass which previously existed. The increase in length was thought by Duhamel to depend on a slow and gradual extension of the parts of a bone; but the rapid elongation that occurs before the consolidation of the epiphyses, probably results from the addition of ossific matter at its extremities. This opinion is supported by the following experiment performed by Hunter; he bored two holes in the tibia of a young pig, precisely two inches asunder; some time after, when the bone had increased in length, the animal was killed, and it was found that the distance between the openings was exactly the same.

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* The existence of the epiphyses in children, explains the peculiar fracture which sometimes occurs in the articular extremities of the long bones. In this accident, called *diastasis*, the epiphysis is torn off; but there is no crepitus, because the lacerated cartilage does not produce that grating, on motion, which is such a diagnostic mark of the common fracture.

SECTION III.

EXPLANATION OF THE PHENOMENA OF OSSIFICATION.

THE cause of ossification and the parts which are concerned in that process, were till a late period but little known, and even at the present day our information on these subjects is imperfect. It is not, however, my intention to enter into the details of the various theories which have successively occupied the attention of physiologists. I shall confine myself to alluding to a few of the most celebrated doctrines which have been advanced to explain the phenomena of ossification.

The anatomists who were contemporaries of Daventer, supposed that bone was formed of an osseous juice, which, passing through the conditions of a thin and transparent cartilage, and of a soft and flexible bone, became at last, by a slow coagulation, a firm, hard, and perfect bone. According to this opinion, the production of bone depended more on the mechanical hardening of the exuded fluid, than on the action of the blood-vessels.

The theory of Duhamel was more plausible, and being founded on an extended series of experiments, it was very generally admitted. This ingenious naturalist contended that the bones are formed by successive layers, deposited from the periosteum in the same manner as the rings of wood which are seen in the trunk of a tree, are deposited from the inner bark; and he supported this opinion by the effects which he observed from feeding animals on madder. It is known that the colouring principle of this substance, owing to an affinity that exists between it and the phosphate of lime, tinges the bones of a red colour, while the soft parts remain unchanged. Now Duhamel asserted, that by giving madder to a young animal for a time, suspending the use of it, and then beginning again to give it, he found, on examining the bones, that they exhibited alternate layers of a red and white colour, which layers he thought corresponded to the periods when the madder was given or withheld. From these experiments he concluded that the bones are formed of concentric laminæ, which are deposited from the periosteum.

Mr. John Bell has pointed out, in the forcible and expressive manner for which he was so justly celebrated, the contradictions and inconsistencies of Duhamel's theory. But while we admit the general truth of this criticism, it must be recollected that the investigations of Mr. Howship and of Beclard, prove that, in certain stages and forms of ossification, the bony matter is undoubtedly secreted from the vessels of the periosteum; and Mr. C. Bell even states that in his museum there was the bone of a pig, in which three separate layers could be distinguished by their colour.

The hypothesis of Duhamel was controverted by Haller, who concluded that the bone was formed by its internal vessels, altogether independently of the periosteum. This account is much nearer the truth than the former; but still, as we have shewn in the previous description of ossification, it is not free from error.

Some modern writers seem to think that the phenomena which occur in the growth of bone, are more inexplicable and mysterious than those which attend the formation of other organs of the body. Thus it has been asked what is the origin of the phosphate of lime? What cause determines it to pass into those particular arteries which go to the bones? And how is it separated in the minute vessels from the other parts of the blood? Is it, as some authors have contended, poured out from the ends of the small arteries; or is it deposited from pores placed on their sides; or, lastly, does it accumulate in the vessels, and so convert them into bone? We may reply, in answer to these queries, that the earthy substances employed in the generation of bone, are without doubt introduced into the system in the same manner as the various other materials which are required for the development of the animal frame; that they are mixed with the mass of the circulating fluids; and that eventually, by the influence which the arteries, in virtue of their vitality, exert on their contents, those particles are separated from the blood, which are necessary for the growth of the bone. I acknowledge that we are totally ignorant of the means by which the aliment is changed into such a compound fluid as the blood, and also how the constituent parts of the latter are separated in the various organs so as to accomplish their nutrition. I simply wish to state, that there is nothing more wonderful or peculiar, for all is wonderful, in the formation of a bone, than of a nerve, a muscle, or a ligament.

SECTION IV.

OF THE REPARATION OF FRACTURED BONES.

THE union of fractured bones is so immediately connected with the process of ossification, that I conceive a few observations concerning the manner in which it is accomplished will not be deemed misplaced. The older anatomists attributed the production of *callus*, by which term is understood the substance connecting the broken ends to the exudation of an osseous juice, from the surface of the fracture, which, gradually acquiring consistence and hardness, at length united and soldered together the fragments. This opinion reigned in the schools till Duhamel, towards the middle of the last century, opposed it by publishing the results of his experiments. He found that shortly after a bone was broken, the periosteum being thickened and inflamed, was glued to its outer surface, and that in a few days later, when the swelling of the membrane was increased, its internal layers were converted into cartilage, and ultimately into bone. From the result of his extended inquiries, Duhamel concluded that the periosteum was the part principally concerned in the reparation of fracture.

This doctrine was supported by many excellent anatomists, and, amongst others, by the second Monro, who is so deservedly celebrated for the soundness and extent of his knowledge. We shall see presently, that the statements of Duhamel, notwithstanding the discredit that has been thrown on them, accord in many respects with the latest and best accounts which have been given of the formation of callus.

Haller, who adopted the ancient hypothesis, directed a great number of experiments to be made by Dethlef, the results of which confirmed him in his ideas. He attributed the generation of callus to a juice which was derived from the internal vessels of the bone itself, and which, being thickened by degrees, became first cartilaginous and then osseous; without the periosteum being in any degree connected with these changes.

The opinions of Hunter, although in some respects imperfect, are extremely valuable, and correspond, in many essential particulars, with the recent scientific experiments of Howship, Dupuytren, and Breschet. This eminent physiologist informs us, that "the space between the broken surfaces of the bones and the surrounding parts, is at first filled with extravasated blood from the ruptured vessels. This first coagulates, and then becomes vascular. The ends of the bones are attacked with the adhesive inflammation, in consequence of which a new operation takes place in these parts. This inflammation which takes place, takes place equally in any detached parts called splinters, but such as are still attached to the soft surrounding parts and to the bone." "There is an absorption of the angles and sharp edges, by which the processes are taken off and rendered smooth. I also believe, that in most fractures there are some splinters detached, but they are kept alive still, provided they are not deprived of the living principle themselves, nor the surrounding parts deprived of it, and form a part of the callus. If the laceration is great in a compound fracture, they may increase the quantity of callus in proportion to the distances between the divided surfaces of the bones. This new formed substance is a *nidus* for the bone; it becomes more and more vascular, and firmer and firmer, till it becomes cartilaginous. The ossific process begins at the original bones themselves, and extends into the callus, though the formation of bone begins in different parts of the callus, similar to epiphyses." This account shews, that Mr. Hunter considered the general laws which regulate the union of fractures, to be the same as those he has so admirably described in the union of divided soft parts.

The ingenious and exact investigations of Mr. Howship have determined most of the disputed points connected with this question, and have also explained several of the causes that have been most fertile in producing the diversity of opinion which has so long existed among physiologists. These facts perfectly accord with those ascertained by Dupuytren and Breschet, and therefore they may be received with the greater confidence. There is so much resemblance in the conclusions of these observers, that it would be an invidious task to apportion the credit that each individual deserves; but it is due to the character of the English experimentalist, to state, that although the papers of Dupuytren and Breschet had the priority as to publication, there is no reason to suppose that they were known to Mr. Howship previous to the appearance of his memoir.

We learn from the united labours of these physiologists, that the first effect produced by a fracture is the effusion and coagulation of a large quantity of blood, which is derived from the lacerated vessels of the bone, of the periosteum and even of the surrounding structures, the quantity being proportioned to the violence of the accident. This coagulum surrounds and unequally adheres to the broken ends, and a portion of it is deposited within the opening of the medullary canal, with which it is connected; the periosteum is also completely charged with the effused blood. The vascularity of the medullary membrane in the seat of the fracture is greatly increased, producing a bright vermilion coloured surface, in which, with the aid of the microscope, the vessels may be seen quite entire. In the femur of the rabbit, no arteries could be detected passing into the coagulum, as late as the fifth day after the fracture. In a few days afterwards, the colouring part being removed, the extravasated blood becomes pale; at this period the periosteum is greatly thickened, and has been even found a quarter of an inch in thickness; it has a transparent pearly hue, and assumes by degrees the characters of true cartilage. The swelling and firmness of the periosteum and of the surrounding parts, appear to be a provision of nature to guard against the least disturbance or motion between the fractured ends during the act of union.

A deposit of osseous matter is made in the cartilaginous periosteum, and also in the coagulum that closes the medullary cavity; it is worthy of remark that in the latter part, the deposition, as in the original formation of bone, advances from the circumference towards the centre of the coagulum. Mr. Howship found that the fractured ends of the femur of a rabbit were covered on the twenty-third day with a considerable quantity of new bone, clothed externally with a well injected membrane or periosteum. After the bone is firmly united by the callus which is deposited between its extremities, the thickened periosteum and the surrounding soft parts are gradually restored to their original condition; and the ossific matter, which had been temporarily secreted so as to form an external callus, is slowly removed by the action of the absorbents.

Baron Dupuytren concludes from his investigations that there are two distinct processes in the union of fracture, or rather that a double callus is formed. The first, which he calls provisional callus, "cal provisoire" is formed by a deposition either in the periosteum alone, or in that membrane and in the cellular, and even in the muscular tissues. This secretion forms a kind of clasp which surrounds the broken ends and also adheres to them. At this period the surfaces of the fracture are not united, but they are surrounded and supported by the new formation. In the space of four or five months, provided there has been perfect coaptation and there is no irregularity around the fragments, the osseous substance which has been temporarily produced, decreases in quantity, and the periosteum and the cellular tissue return to their original condition; lastly, at about the eighth month, the definitive or permanent callus is formed, by which the surfaces of the fracture are firmly joined.

This theory is very similar to that of Duhamel, the principal difference consisting in this:—that M. Dupuytren considers the thickening and ossification of the periosteum to be a temporary and provisional change; whilst Duhamel supposed that the fractured bone was actually consolidated and united by means of the periosteum. It ought to be stated, in justice to this distinguished naturalist, that he thought the medullary membrane, as well as the periosteum, was swollen and ossified, and that the fracture was firmly consolidated by the meeting and union of these two membranes.* This opinion very nearly agrees with Mr. Howship's experiments.

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* Mém. de l'Acad. Roy. des Sciences. Année 1741, p. 108.

CHAPTER TENTH.

OF THE MUSCULAR SYSTEM.

THIS system consists of a great number of bodies, named *muscles*, which are distinguished by their fibrous structure, by their reddish colour, and especially by their power of shortening or contracting their fibres on the application of a stimulus. They constitute what, in common language, is called the flesh of animals.

The general muscular system requires to be divided into two great classes, viz. into the muscles which are under the controul of the will, and into those which are beyond its influence. The former are called the muscles of volition, of the animal functions, or of animal life; and also, from their situation, the external muscles. The latter are known by the terms of involuntary muscles, muscles of the organic or vegetative functions; and from their form and connexions, hollow and internal muscles. The organs belonging to these two classes differ considerably from each other in their form, and in the disposition of their component parts; and still more so in the phenomena of their actions. These differences are indeed so great, that some writers have considered the two sets of muscles entirely apart from each other; but as there are many properties which they share in common, it will simplify their description and prevent repetition if the general characters of the muscular system be first examined, and then the peculiarities by which each division is distinguished.

PART FIRST.

OF THE MUSCLES IN GENERAL.

These organs occupy a large proportion of the whole body, and by their bulk they constitute a great part of its weight. In the most simple animals there are no distinct muscular fibres, although certain movements are performed, which it is thought are produced by the contraction of the cellular tissue. In those classes in which a muscular structure becomes first apparent, it only acts on the tegumentary membranes to which it is attached. But in the vertebrata, in which the muscles are greatly developed, they are principally connected with the various bones of the skeleton, a few only being attached to the skin and mucous membranes, and to the organs of the senses and voice.

Section I.

DISPOSITION AND FORM OF THE MUSCULAR FIBRES.

The muscles consist of bundles of fibres, which are themselves composed of more delicate filaments, held together by a loose cellular tissue. This structure is visible to the naked eye; but a powerful lens is required to ascertain the more minute texture of the part. If one of the most delicate filaments be placed on a piece of glass, lines may be seen by the microscope, which run parallel to the direction of the fibre, indicating a further division than had previously been detected; at length a fine thread is observed, which, being incapable of division, has been called by writers the *ultimate muscular fibre.* Various terms have been employed in order to designate these successive divisions. Muys, a Dutch anatomist, who paid great attention to this subject, divided the muscular substance into fibres, fibrillæ, and threads; and he subdivided these again into several gradations, so that he made no less than nine divisions, successively diminishing; the fibrils, of which the last series is composed, being some hundred times smaller than the finest hair. Other observers have rejected this analysis as altogether imaginary; but in doing this they have committed a much more serious error, by admitting an indefinite divisibility. It is almost needless to state, that in the muscles, as in all other material substances, we must arrive by microscopic inspection, provided our instruments be sufficiently powerful, at a degree of division which is ultimate and determined.

It will answer every useful purpose if the muscle be divided into *fasciculi*, *fibres*, and *filaments;* by the first word is understood those bundles which are seen by the naked eye to consist of distinct fibres; the second term should be applied to the smallest division that can be perceived without the assistance of a magnifying power; and lastly, the term filament, corresponding with the *ultimate fibre* of authors, indicates the last division of which the muscular structure is susceptible.

The *fasciculi*, called also *lacerti*, are much more apparent, from their great size, in some muscles than in others; thus they are very large in the gluteus maximus, the deltoid, the carneæ columnæ of the heart, and in the longitudinal bands of the colon. In other instances they are indistinct, and there are even muscles, which in their entire bulk, scarcely equal the volume of a part of one of the preceding bundles.

The *fibres* differ from the fasciculi by being almost always of the same size; their form, which is prismatic pentagonal, or hexagonal, but never cylindrical, is nearly the same in all parts; they can be shewn, by a longitudinal dissection, but they are more distinctly seen by cutting the muscle transversely, especially after it has been boiled, or macerated in alcohol. The fibres appear to extend in a continuous manner, from one extremity of the muscle to the other, and this, according to Prochaska, Bichat, and others, is actually the case, even in such long muscles as the sartorius. But a different opinion was entertained by Albinus and Haller, who thought that each fibre was jointed or made up of a number of pieces. Inspection seems to confirm the former statement, so that the length of the fibre being determined by that of the muscle, must be extremely various.

The *ultimate filament* is so very minute, that a high magnifying power is required to render it apparent; this great tenuity and the uncertainty of microscopical observations, are the causes of the contradictory accounts which have been published on this subject. From the time of Leeuwenhoek, to the present day, anatomists have been occupied in endeavouring to determine the exact composition, size, and other qualities, of the ultimate fibre, but with such little success, that scarcely any two writers agree in their conclusions. As there is so much discrepancy in the opinions of the highest authorities on this subject, I shall only allude, in a brief manner, to the latest researches which have been made in this country and on the continent.

Sir A. Carlisle, who has published some instructive observations on the anatomical structure of the muscular fibre, states that it is undoubtedly a solid cylinder, the covering of which is reticulated membrane, and the contained part a pulpy substance irregularly granulated, and of little cohesive power when dead. It is distinctly affirmed, that the intrinsic matter of muscle contained within the ultimate cylinder, has no red particles.

Subsequently to this description a very different account has been given by Mr. Bauer and Sir E. Home. At the request of the latter, Mr. Bauer examined, with the aid of high magnifiers, the ultimate muscular fibre, and he found that it was composed of a series of globules of the same size with those of the blood, when deprived of their colouring matter; it is even stated that when the fibres are macerated for a sufficient time, having been previously boiled or roasted, they may be readily broken down into a mass of globules. The diameter of the particles of the blood, when deprived of their colour, and consequently of the muscular filament, is $\frac{1}{2000}$ part of an inch.

The idea of a globular structure is not of modern origin. Leeuwenhoek, in his first publication,* affirmed that the fibres were composed of globules; it is true, he afterwards changed his opinion, and contended against Hooke, that the globular appearance was deceptive, being produced by the unequal reflection of light from numerous transverse folds which he had observed on the fibres. The existence of globules, or of corpuscles having nearly the same form, was admitted by many celebrated anatomists after Leeuwenhoek; thus the muscular fibre was often compared to a series of pearls, to grains of coral, rows of beads, &c.

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* Phil. Trans. 1674.

The researches of several modern continental physiologists, amongst whom may be enumerated Dumas, M. Edwards, and Dutrochet,* correspond in their essential points with those of Mr. Bauer.

Notwithstanding the high authorities who contend for the globular structure, and the very general assent this doctrine has received, I am induced, from the investigations of Dr. Hodgkin and Mr. Lister, and from my own observations, to doubt its correctness. I have repeatedly examined, with the assistance of my friend, Mr. T. Cooper, the muscular fibre. We have uniformly found, by using a magnifying power of 300, that an immense number of minute transverse lines could be perceived crossing the fibres, which were in some parts divided from each other by longitudinal lines apparently marking the lateral boundaries of the fibres; in most places, however, the small transverse lines were not separated from each other by any distinct division. Several large fibres were also seen crossing the lines in different directions, which appeared to consist of cellular tissue.

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* This distinguished anatomist and naturalist has published some interesting remarks on the structures of animals and plants. He states that the intimate composition of muscle is difficult to detect in the vertebrata, but that in several of the inferior animals it is readily discovered. The muscular fibres of the cray-fish are composed of transparent fibrillæ disposed longitudinally, in the intervals of which there exist a great quantity of transparent globules placed irregularly, and called by Dutrochet *muscular corpuscles;* he designates this structure, *fibrillo-corpuscular tissue.* In the heart of the above animal the fibrillæ are few in number, but the corpuscles abound; the latter are also observed to be arranged in longitudinal series, forming what are named *articulated muscular corpuscles.* In some of the mollusca, as the garden snail, it was ascertained that the heart, which is in general the most favourable part for microscopical observation, is entirely composed of agglomerated muscular corpuscles, some of which formed longitudinal series, whilst others were aggregated together without any regular order. We learn from this examination, that the existence of fibrillæ, and even that of linear organs in general, is not an indispensable condition of muscular motion. This fact I consider important, as it may explain how the movement of these animals, as the Zoophytes, which have no evident muscular organs, is produced. Anatomists have hitherto referred this movement to a contractile cellular tissue.—*See Recherches sur la Struc. Intime des Animaux et Vegetaux.*

In reviewing the preceding statement the reader will be struck with the discrepancies it presents, and which display a humiliating exemplification of the imperfection of all our attempts to determine the intricate structure of the animal body. But much of this contradiction I believe to be only apparent, depending on the successive improvements that have been made in the powers of the microscope. It is probable that physiologists, from the time of Leeuwenhoek, have described what they really saw with their defective instruments; so that if we reject the speculative arguments which were founded on these imperfect observations, a general resemblance may be traced throughout their descriptions. Is it not, for example, probable that the rhomboidal vesicles of Borelli—the series of pearls observed by Hooke—the rounded corpuscles of the Wenzels, and the wrinkles noticed by Prochaska and Fontana, are in reality the identical structures discovered by the powerful miscroscope of Hodgkin and Lister?

In concluding these remarks I shall quote the following passage from Richerand, with whose opinion I entirely coincide. "To explain the phenomena of muscular action, it is sufficient to conceive each fibre as being formed of a series of molecules of a peculiar nature, united together by some unknown medium, whether that be oil, gluten, or any other substance but whose cohesion is manifestly kept up by the vital power, since the muscles yield, after death, to efforts by which, during life, they would not have been torn."

SECTION II.

ORGANIZATION OF THE MUSCLES.

THE peculiar tissue of the muscular system consists of the fibre above described; it also possesses cellular membrane, blood-vessels, lymphatics, and nerves.

The cellular membrane enters very largely into the composition of these organs; in fact there are but very few parts of the body that contain a greater proportion of that substance. It has a two-fold disposition in the interior of the muscle; one portion of it investing the fasciculi and fibres, and another intervening between them. We readily perceive, with the naked eye, that the large bundles are covered by membrane which is rather condensed, and it is also evident that the fibres are enclosed within sheaths of the same structure. With respect to the ultimate filaments, it is probable that each of them is surrounded by the cellular tissue, constituting a tube which contains the muscular pulp. The successive divisions of the muscle are loosely tied together by a reticular substance, which contains some fat and an albuminous fluid, destined to lubricate the component parts, and to facilitate their movements. It has been thought, but with little foundation, that in addition to the common fat, muscles possess a peculiar oil intended to prevent adhesion and friction between their fibres. The partitions are sometimes so large as to divide the muscle into two or more parts; such is the septum which separates the clavicular from the sternal portion of the pectoralis major.

In addition to the cellular substance placed in the body of the muscle, there is a layer, which covers the external surface, so as to surround the entire organ, and thus insulate it from the neighbouring parts; the thickness and density of this layer are liable to great variation, but in general it is most developed on the large muscles of the trunk, where it seems to supply the place of fascia. This common connecting medium has very important uses; in general, it fixes the muscles in their places, and by uniting the fibres together, it combines their action in a remarkable manner; when this substance is removed, their contractions become vague and irregular.

The blood-vessels of this system are very numerous, and of large size; so that, with the exception of some of the viscera and the mucous membranes, they are more abundantly supplied with blood than any other organs.

The arteries usually enter nearer to the centre than to the extremities of the muscle; they pass, at first, between the fasciculi; each soon divides into two branches, which run lengthwise in the intervening cellular tissue; they subdivide into minute vessels, and ultimately ramify on the cellular sheath of the muscular filament. The mode of connexion between the capillary arteries and the matter of the filament escapes observation. The veins are arranged in two orders; some accompany the arteries, and the others run superficially on the surface of the muscles. The small radicles form a vascular network, the blood of which is afterwards discharged into larger branches, and, at length, into the neighbouring trunks.

The lymphatics are not so numerous as the blood-vessels; they do not appear to extend to the muscular fibre, but to arise from the interstitial cellular substance.

It has long been remarked that the muscles which are under the control of the will, receive very large and numerous nervous cords; and, on the contrary, that the involuntary muscles, in proportion to their size, are sparingly supplied. The nerves of volition are derived from the cerebro-spinal axis, and those of the hollow muscles almost entirely from the system of the sympathetic. The nervous cords of the voluntary muscles as they proceed towards their distribution, form large, and in some places intricate communications, called *plexuses*, which have an essential influence in associating the muscular actions. The nerves of the sympathetic also constitute numerous plexuses, in which they have not only communications with each other, but also with the nerves of the preceding class. This connexion, and the still more important one that exists between the cerebro-spinal system and the ganglions, place the muscles supplied from the latter source in a peculiar manner under the general influence of the nervous system.*

The filaments of the nerves in general accompany the sanguiferous vessels, particularly the arteries; they penetrate the muscles in different points, and, after many divisions, they become so minute as to escape all observation. Their ultimate termination is in consequence unknown, although many attempts have been made to detect it. Sir A. Carlisle states that the last subdivisions of the nervous fibrils are perfectly visible to the naked eye, and that where they seem to end, they leave a large portion of the muscular structure unoccupied by them. The medullary substance, together with the enveloping membrane of the extreme fibrillæ, become soft and transparent, and thus the whole fibril being rendered indistinct, seems to be diffused and mingled with the substances in which it ends. The ultimate termination is stated to be in the *reticular cellular membrane of the muscle.*[*] Prevost and Dumas have also published more recently observations concerning the disposition of the nervous filaments. These physiologists differ from all others, by supposing that the filaments do not in fact terminate in the muscles, but that they return on themselves, and pass either to the trunk which furnishes them, or they anastomose with some other neighbouring nerve.

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* Philip's Experimental Inquiry, p. 101, p. 263.

It is certain that the nervous fibrillæ, however they may really end, are not sufficiently large or numerous to supply each individual muscular filament. It therefore may be asked, how can they act on all the fibres of the muscle? Two hypotheses have been suggested to explain this difficulty. Sir A. Carlisle and Isenflamm suppose that the cellular tissue of the muscles, in which they conceive the nerves to terminate, acts as a conductor for transmitting the nervous influence. Reil and others, on the contrary, imagine that the nerves have the sphere of their activity extended beyond their termination, by what is called a *nervous atmosphere*.

In concluding this account of the organization of muscles, it is necessary to state, that they are usually connected by the extremities of their fibres with a tendinous structure; this remark applies, however, almost exclusively to the muscles of volition.

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[*] Philos. Trans. for 1805, p. 9.

SECTION III.

CHEMICAL COMPOSITION.

IT is extremely difficult, if not impossible, to make a very minute analysis of muscle, on account of the membranous matter and blood that remain inseparably united with it.

If thin slices of the muscular substance be exposed to the action of air, they become dry, hard, and of a dusky brown colour; if too thick a portion be thus treated, it does not dry, but is decomposed, and assumes a green and livid colour. When the muscular fibre has been macerated for a sufficient length of time in water which has been frequently changed, it becomes whitish or yellowish, and it is also softened and swollen; by this plan it is obtained in as pure a state as the circumstance mentioned above will permit. The water contains albumen, jelly, various salts, and a peculiar extractive matter, which was first discovered by Thouvenel. This substance, which was named by Thenard, *osmazome*, has a brown colour, an acrid taste, and an aromatic odour; it is thought to be the ingredient which gives the specific flavour to the flesh of different animals.

In young animals the muscles contain a considerable quantity of jelly, but it is doubtful if there is any of it in the adult. The salts that are contained in muscular flesh, or, as some think, merely in the blood-vessels which belong to it, are principally the phosphates of soda, ammonia, and lime, and also the carbonate of lime. Some other saline substances have been detected by Fourcroy, Vauquelin, and Berzelius. The following is the analysis of the last chemist:

Fibrin, vessels, and nerves	15·8
Cellular substance	1·9
Albumen	2·2
Osmazome, with the lactate and hydro-chlorate of soda	1·8
Mucous matter	0·15
Phosphate of soda	0·9
Phosphate of lime, containing a portion of albumen	0·08
Water and loss	77·17
	100·00

Most of the stronger acids and the caustic alkalies dissolve the muscles. When nitric acid is employed, the fibre is partly decomposed and partly dissolved, while a quantity of azote, united to carbonic acid, is disengaged. It is worthy of remark that a larger quantity of azote, which constitutes the basis of animal matter, is extricated from muscle than from any other substance. When the action of the acid is promoted by heat, the muscle is quickly dissolved, and the fluid assumes a deep yellow colour. Besides other substances that are thus produced, a quantity of unctuous matter is seen floating in the form of globules of oil on the surface, which becomes concreted when the fluid cools, and being found to possess properties intermediate between those of fat and wax, it has obtained the name of adipocire.*

SECTION IV.

PROPERTIES OF MUSCLES.

A difficulty arises in examining the physical properties, in consequence of the close connexion which there is between the muscular fibre and the cellular substance, so that it is impossible to distinguish what exact qualities ought to be allowed to each of these structures. It is probable, that most of the properties of this class should be referred to the cellular membrane rather than to the pure fibre itself; but for every practical purpose, it will be sufficient if we regard the properties exhibited in any muscle as being exercised in the entire organ, leaving it to future and more successful observation, to determine how far each individual texture is concerned in their production.

It is well known that in the human species, and more perfect animals, the muscles are of a reddish brown colour. This colour is not, however, an essential property, as it may be nearly removed by repeated washing, without the proper fibrous structure being altered. There are also many species of animals which are distinguished by the velocity of their motions, and yet have white muscles. Some birds, as the black game, have the external pectoral muscles of a deep red colour, whilst the internal ones are pale. The colour, which is generally deeper in the voluntary than in the involuntary muscles, is much influenced by exercise; thus, it is deeper in wild than in tame animals of the same species; it is likewise affected by the kind of death, and many other circumstances. The red colour principally depends on the blood which circulates in the muscle; but it results in part from a peculiar substance, perhaps osmazome, which is combined with the fibres.

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* A very full and excellent account of these chemical properties is contained in Dr. Bostock's work, vol. i. p. 151.

The cohesion of the muscular substance is variable, but in general it is less than that of the membranous structures. This property, which is most developed in the longitudinal direction of the fibres, is considerably diminished when they lose their vitality, so that they may be torn without much difficulty in the dead body.

The extensibility of the muscles, especially of those belonging to the involuntary class, is considerable. The muscular coats are liable to great, and frequently to sudden extenſion, in consequence of the dilatation which the hollow viscera, as the stomach, the intestines, and the bladder, so often experience.

Again, with respect to the muscles of volition, they are generally so disposed, that the contraction of one set, causes another to be extended: thus in bending the knee, the rectus femoris and vasti are elongated or stretched; in these cases the extension concerns the fleshy part alone, as the tendon, from its unyielding character, cannot give way. The extensibility is increased in proportion to the length of the muscle. We obtain from the observation of various diseases, still more striking instances of muscular extensibility; tumours in all parts of the body, in the eyelids, in the mouth, in the neck, &c., distend the muscles which cover them; and the same may be said of aneurisms, of deep abscesses, dropsy, &c.*

The most important of the physical properties is one which has received many different appellations; at least it appears that the various terms of dead force, tonicity or tonic force, contractility of texture, and elastic force, which have been employed by physiologists, are all terms to which the same signification ought to be attached. They express that property, in virtue of which the fibres of all muscles; *independently of vital contraction*, which is of a totally different nature, have a constant tendency to contract or shorten themselves; this property I prefer calling *tonic contraction.* It seems to depend on the elasticity which is possessed by the cellular tissue of the muscle; for, according to Sir A. Carlisle, the intrinsic matter of muscle is not elastic, and Soemmering is also of the same opinion. In whichever of the two parts this property resides, it is certain that the muscles, considered as entire organs, have a permanent tendency to contraction, especially when by lengthening, they have exceeded their natural dimensions. This kind of contraction, which is exercised without the action of any stimulant, is always present when the fibres are not under the influence of a distending force.* It is slow in its operations, and as it is not subject to the alternations of relaxation, it may continue for an indefinite period; in both these respects, it is totally different from vital contraction.

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* It is necessary to add that the muscles only yield in this manner when the distending force is applied gradually; if on the contrary, a tumour is formed suddenly, and particularly if this is accompanied by irritation, the muscles, in place of giving way, will violently resist. An illustration of these two states is sometimes afforded in bronchocele, in which disease the muscles covering the thyroid gland usually yield, and are distended before the tumour, because this is slowly developed, and the enlargement is not accompanied by pain or acute inflammation. If, on the contrary, the swelling is more suddenly formed, and is attended with considerable irritation, the muscles of the windpipe and larynx do not give way, but forcibly resist the growth of the thyroid gland, which is thus pressed back against the trachea, œsophagus, and great vessels of the neck, so as to produce the most urgent and distressing symptoms. I had an opportunity a few years ago, of dissecting the body of an aged female, whose death was caused by the pressure of such a tumour on the windpipe; in this case the omohyoideus had so greatly resisted, that it had formed a deep furrow, of sufficient size to receive the little finger, in which it lay imbedded.

The examples of this species of contraction are so very numerous, that I must confine myself to enumerating two of the most remarkable. When a muscle has been distended by any cause, as soon as the extending power ceases to act, the organ recovers its original state by this property. It must be remarked, however, that if the extension has been long continued, or frequently repeated, the subsequent retraction will be imperfect, because the muscular tissue becomes weakened by the state in which it has been kept.† Again, the division of a living muscle produces two phenomena, which are manifestly the result of tonic contraction: 1st, the two ends retract from each other, leaving a space between them proportioned to the extent of separation; 2nd, the antagonist of the divided muscle, having no longer any effort to overcome, contracts in virtue of its elasticity, and thus draws the part to which it is attached in the direction of its fibres.

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* Fordyce—Croonian Lecture, p. 30, 1788.

† Bichat instances the relaxation produced in the abdominal muscles, by several pregnancies. He also relates the case of a man, which occurred in the practice of Desault, from whose mouth a fungus had been removed; in the cheek several large wrinkles remained, which depended on the imperfect contraction of the muscles. A more remarkable case was some years since published by my father, (see Medical and Surgical Remarks, p. 100,) of a man, from whose mouth he removed a large tumour which had pressed the tongue completely to the opposite side. After the operation this person found that he had no control over the tongue, which tumbled about in his mouth, so as to render his articulation worse than it was before the removal of the swelling; in time, however, the lingual muscles were restored to their proper condition.

The tonic contraction is weakened, but not destroyed, by death; it continues for a longer or shorter period after the extinction of life, and is generally thought to be the cause of the stiffness which is observed in the corpse; the commencement of decomposition alone seems to produce its annihilation.

The vital properties consist of sensibility and contractility, but it is to the latter power that the muscles owe their peculiar and decided characters.

The sensibility of these bodies is rather obscure, but there are sufficient proofs of its existence. When, for example, these organs are divided in an amputation, or when they are pricked in a living animal, pain is caused, although this is not so great as when an equal degree of injury is inflicted on many other parts. The feeling of lassitude, amounting sometimes to pain, which is produced by continued muscular exertion, and with which every one is familiar, is doubtless owing to the same property. This sensibility, like that of all other organs, is of a peculiar character; it serves to inform the mind of the condition of the muscles, and as it is excited by continued motion, it warns us when rest is required, and thus prevents the action being prolonged to an injurious extent.

Some modern writers have attributed to the muscles a particular faculty, which they have called the *muscular sense*. Although there is no doubt that such a power does exist, yet it ought to be considered merely as a modification of the sensibility just mentioned. It is by means of this property of the muscles, that in moving our limbs we are informed of their exact situation with respect to the body, without the assistance of the external senses; and that we *feel* the least change in the position of the body. A more striking illustration of this sensation has been offered by Mr. Bell: any substance placed in the hand may be weighed as it were, and by practice this may be done very accurately. On what does this depend? Are we not enabled to judge of the weights of different bodies so placed, from estimating the quantity of muscular power which they respectively require to support them.* It is necessary to state that the sensibility of muscle is quite distinct from that property which Haller described by the name of *vis nervea*. He expressed by that term, the power in the muscular fibre which enables it to receive impressions conveyed to it by the nerves; but as that power, as far as we know, is not at all different from the property of the fibre by which it receives any other impression, either mechanical or chemical, it would be objectionable to distinguish it by a particular name.

The most important and interesting property of muscles is that, in virtue of which they have the power of contracting or shortening themselves on the application of a stimulus, and by which they produce the various movements so strongly characteristic of animal existence. It has been well observed that the first sensible operation of life is muscular motion; and that the numerous combinations of this motive faculty sustain and carry on the multiplied functions of the largest animals; so that its temporary cessation causes the suspension of the living powers, and its total quiescence—death. This property has generally been denominated by modern physiologists, *irritability*, a word which was employed by Haller, who also used the term *vis insita*. Blumenbach calls it *vis muscularis;* Chaussier and many continental writers, *myotilité*, *motilitas;* and Bichat, *animal contractility*. I agree with Dr. Bostock in preferring the term of contractility; because this forcibly expresses the peculiar power enjoyed by muscle, without involving any theory as to its source.

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* The voluntary muscles receive sentient as well as motor nerves; the property alluded to above depends, without doubt, on the former set. The reader will find some interesting observations respecting the influence of sensation on muscular action, in Mr. Mayo's Outlines of Physiology, p. 335, p. 343.

SECTION V.

OF MUSCULAR ACTION.

THE investigation of muscular contractility embraces so many subjects of importance, that I shall confine myself to some general observations on those points which possess the greatest interest.

PHENOMENA OF MUSCULAR ACTION.

When a muscle contracts, it becomes shortened, and the two ends are approximated;* its belly swells, and becomes hard and firm to the touch; the surface presents numerous wrinkles and furrows, and the fibres are in a state of oscillation, which is caused by very rapid vibratory alternations of contraction and relaxation. During this state, the bulk and specific gravity do not appear to be altered,* nor does the colour of the muscle seem to be affected. When the contraction is finished, all these phenomena disappear, and the muscle becomes relaxed.

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* The fibres, which are straight, while at rest, are stated by some modern authorities, to approximate each other in a regular manner when they contract, so as to form zig-zags, and shorten the distance between their extremities. It is also asserted by Prevost and Dumas, that the nervous filaments penetrate to the muscular fibres, exactly at the angles, which are produced by this kind of contraction. The approximation of these filaments, which they consider as an electric phenomenon, is thought to draw the muscular fibres into angles, and thus to be the cause of muscular contraction.

The duration of muscular action is limited within certain bounds, so that after it has continued some time, relaxation necessarily occurs. Common experience proves, that in performing any laborious or continued movements, we are at length compelled, notwithstanding the greatest desire to the contrary, to desist, and to wait till the muscles have been recruited before the exertion can be resumed. In general, it appears that the period of rest which is required, is proportioned to the degree of previous exhaustion; thus, in some of the involuntary muscles, as the heart, although the cessations are only momentary, they are sufficient to restore the power of the fibres; whilst, after long continued and violent exercise, a considerable time elapses before the muscles recover themselves.

The observations of Dr. Wollaston prove, that the individual fibres are subject to very rapid alternations of contraction and relaxation, so "that each effort, apparently single, consists, in reality, of a great number of contractions repeated at extremely short intervals." We may conclude from this interesting fact, that during the action of a muscle, some of its fibres contract, while others are relaxed.

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* The increase in the thickness, which is observed during contraction, has induced some physiologists to conclude that the actual size of the muscle is augmented; whilst others, on the contrary, think that the size is diminished. Mr. Mayo has proved, by an ingenious experiment, that there is no alteration in the bulk of a muscle during contraction; and has thus shewn that neither of the above opinions is well founded.

Relaxation is generally conceived to be a passive effect, but when parts have been displaced by contraction, there is a necessity for some absolute power to bring them back to their former situation. In many parts of the body the action of the antagonist muscles, or the force of gravity, will replace the muscles as soon as their contraction ceases; and in other instances the elasticity of the parts which have been moved, as the cartilages of the ribs or larynx, will produce the same effect. But as the involuntary muscles are so arranged, that these causes cannot influence them, many physiologists have contended that these muscles, and even those of volition, possess an *active power* of relaxation. This doctrine is rendered very probable by the observations that have been made on the action of the heart and intestines. If the heart be removed from a living animal, and emptied of its contents, the pulsations still continue. Now, if in this state the organ be grasped with the hand, it will be found that in dilating it exerts a considerable effort; indeed the force of dilatation is so great, that no pressure by the hand can overcome it.*

The velocity of muscular contraction is very great, although from the circumstance of our being so familiar with it, it does not usually excite our surprise. In the act of running the velocity is very considerable; and in rapid enunciation the number of distinct contractions that take place, during a very small space of time, in order to form the necessary combinations of vocal sounds, is really astonishing.

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* Bichat, Anat. Gen. t. ii. p. 467. The influence of this active power of dilatation on the circulation of the blood has already been noticed. See p. 294 of this work.

The force of the muscles in their state of activity is immense, and is sometimes sufficient to produce fracture of the bones, and rupture of the strongest tendons in the body. The power of the voluntary muscles is, to a certain extent, regulated by the will of the individual, being proportioned to the degree of stimulus communicated through the nerves.

It is difficult to determine the extent of muscular contraction, although it is generally in proportion to the length of the fibres. It has been stated that the voluntary muscles are diminished one-fourth of their length; but the shortening sometimes amounts to one-third. In the hollow or involuntary muscles, the contraction is much greater.

CONDITIONS OF MUSCULAR ACTION.

It is essential that the muscle be in a state of integrity; if this be impaired, the muscular energy is diminished or destroyed; thus the ligature of the arteries of a muscle, by stopping the circulation, causes a loss of power; or again, if the dark blood is prevented returning, by tying the veins, a similar effect is produced. Contusion of the muscles, inflammation of their structure, the accumulation of fat between their fasciculi, &c. are so many causes which more or less oppose their action; in fact, any alteration that deteriorates their organization will produce the same effect.

The observations of the physiologists of the time of Haller, have satisfactorily ascertained, that a muscle can never exert its contractile force without being previously excited by a stimulant. Various agents are capable of determining muscular contraction; in fact, every body in nature is a stimulant to the muscular fibre, because, independently of any other quality, the mere contact of a material substance produces this effect.* Notwithstanding the diversity and unlimited number of stimulants, they may be referred to three classes; 1. *Vital;* 2. *Mechanical;* 3. *Chemical.*

Those of the first species always act through the medium of the nervous system; they consist of volition and of those emotions of the mind which are called passions. The stimulus of volition is exerted only on one of the great divisions of the muscular system, comprehending what are therefore called, the voluntary muscles; but with respect to powerful mental emotions, such as fear, joy, &c. they extend their influence to every muscle in the body, although they produce more effect on the voluntary than on those of the involuntary order.

Mechanical stimulants may excite contraction in different modes, viz. by acting on the brain, on the spinal cord, on the nerves, or directly on the muscles themselves. The stimulants of this class are better calculated to excite the muscles of voluntary motion than the heart.

The stimulants of the chemical kind act on both sets of muscles in the same manner as the preceding, but they more powerfully influence those of the involuntary class.

The peculiar stimulants, as the blood, alimentary substances, &c. which determine the contraction of the heart, stomach, &c. probably act both on the principle of mechanical and chemical excitants, but particularly of the latter.

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* Bostock, Elemen. Sys. of Phy. vol. i. p. 173.

The last condition of contractility refers only to the muscles of volition. In the healthy and natural state of the economy, these organs being excited by the influence of volition, require an uninterrupted communication with the brain for the performance of their functions. Any thing which destroys the connexion between these parts, interferes with the voluntary motions of the body; thus the section of the spinal cord or of the nerves going to any individual muscle, will cause paralysis of the parts cut off from communication with the brain.

From the preceding observations we learn that the exercise of voluntary motion requires three conditions: 1. A sound state of the muscle. 2. A free and uninterrupted communication with the brain. 3. A healthy state of the brain, or rather of that part of it through which volition is exerted.

For the production of the involuntary movements, only two conditions are required: 1. A sound state of the muscle. 2. The action of its accustomed and appropriate stimulus.

CAUSE OF MUSCULAR ACTION.

This inquiry, which has excited an unceasing interest amongst physiologists, has hitherto been conducted with little success, so that it still remains involved in obscurity. Such being the case, I shall not allude to the numerous theories which have been contrived to explain this question; nor shall I offer any surmises of my own as to the source of the wonderful power of muscular motion. There is, however, one point to which attention may be beneficially directed; viz. the connexion that exists between the muscular and the nervous systems, and the share that each enjoys in the production of motion. The investigations of Haller and of succeeding physiologists, seem to prove in a most convincing manner that contractility, or, to use a more common expression, irritability, is a property inherent in the muscular fibre, and independent of the nervous influence; and that it is essentially the same in all muscles, whether voluntary or involuntary. The action of the voluntary muscles is, however, under the immediate control of the nervous system, which transmits the influence of volition, and thus serves to excite the fibres to contract.

EFFECTS OF MUSCULAR ACTION.

In concluding these observations on muscular action, it is necessary to allude to the effects which are produced by it in the animal body.

The muscles are the agents by which all motion, either general or partial, is produced; in the former instance, they move the body from place to place, constituting locomotion; in the latter, they act on its individual parts, both fluid and solid. These movements, however complicated they may appear, depend on the contraction or shortening of the fibres by which their ends are drawn towards each other. It usually happens, during the action of the muscle, that one of its extremities is fixed, and the other moveable; this fixedness is either absolute or relative. We have an example of the former condition in the action of the muscles of the eye, the origin of which is perfectly immovable; the second state is illustrated by the contraction of the flexor muscles of the fingers, during the bending of the fore arm, in which action the origin is only comparatively fixed. In some muscular contractions both extremities are fixed; this generally occurs in the muscles which act on the cavities of the body; as in the instance of those of the abdomen compressing the contained viscera in the excretion of the fæces. In the hollow muscles there is generally no proper fixed point, so that all their parts are equally moveable; this is exemplified in the action of the sphincters, of the circular fibres, of the intestines, &c.

The actions of the muscular system may be divided into the voluntary, the involuntary, and the mixed.

The voluntary actions are those which serve to support the body in the upright posture, and to produce its general or partial movements; they also effect the motions which are necessary to mastication, to voice, to speech, and to some of the senses.

The involuntary actions are principally connected with those functions that are denominated vital, in consequence of being essential to the support of life; there are, however, other motions which are also involuntary, although not of such importance. The involuntary movements may be subdivided into two classes; some are produced by stimulants, which act through a thin membrane, immediately covering the muscles; the movements of the alimentary canal, of the heart, and even of the iris, are of this order; others are determined by a stimulus, the influence of which is propagated by association or sympathy to distant muscles; such are the movements of sneezing, coughing, deglutition, parturition, &c.

Many muscular actions are of a mixed character, so as to constitute a class intermediate to the two former. It is extremely difficult to establish a limit between those movements that are under the control of the will, and those which are involuntary; thus there are muscles which at one time can be directed by volition, whilst at another time they are independent of it. The phenomena of respiration afford a striking illustration of this fact: we are able to regulate the contractions of the diaphragm, and of the other thoracic muscles, in the production and modulation of the voice, in playing on wind instruments, in great efforts, &c.; but we have no power over the same muscles in hiccough or sneezing, and only a limited one in breathing. Again, the motions of the eyelids are ordinarily controlled by the will, but they become involuntary if an attempt is made to strike the eye. Some persons are able to contract the iris by an act of volition,* although in general the pupil is influenced only by light. It is evident that all these actions are of a mixed character.

There is still one question of some interest, that has not been considered in the preceding observations; namely, at what period after death has occurred, do the muscles lose their contractile force? It has long been known to physiologists that these organs retain their contractility for some time after the cessation of the cerebral functions, of respiration, and the action of the heart; but the duration of this period in the different muscles has not been accurately ascertained. It is liable to great variation according to the previous state of health, the kind of death, and the circumstances which have followed it. Diseases, particularly of a chronic nature, have considerable influence on the duration of this phenomenon; the muscular irritability is also speedily extinguished in the bodies of those persons who have been destroyed by respiring noxious gases, as the carbonic acid; and in certain kinds of death, as in that by electricity, the vital powers seem to be so totally and instantaneously annihilated, that the muscles have no power to contract. It has been remarked that the muscular energy is very tenacious in cold-blooded animals, as eels, frogs, serpents, &c.; in these creatures contractions may be excited long after the cessation of the cerebral functions. The duration of contractility in the human corpse varies from one to twenty-four hours.*

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* An instance of this kind is related by Mr. Travers in his Synopsis of the diseases of the Eye. On mentioning this case in my lectures, one of the students informed me he possessed a similar power, which was verified by examination.

Many attempts have been made to ascertain the order according to which the contractile power ceases in the different muscles. This subject occupied the attention of Haller, and other physiologists of the same period; they considered that the heart retained its irritability longer than any other muscle, and that the power was exhausted soonest in the muscles of volition. This rule, however, is liable to many exceptions, which Haller himself noticed; the intestines, for example, frequently continue susceptible of being stimulated longer than the heart. Some experiments have been made more recently by Nysten, on the bodies of criminals who had suffered death by the guillotine. These observations, and others of a similar nature made on animals, shew that muscular contractility is extinguished in the following order: 1. The left ventricle of the heart. 2. The large intestine, the small intestine, and the stomach. 3. The urinary bladder. 4. The right ventricle. 5. The œsophagus. 6. The iris. 7. The muscles of volition, first in those of the trunk, then in those of the inferior extremities, and afterwards in those of the upper extremities. Lastly, in the auricles of the heart, of which the right retains its susceptibility longer than the left. Long after the muscles have lost their power of being excited by the application of galvanism, they remain contracted, and in this manner they produce the stiffness which is so remarkable in the dead body. This phenomenon, which has been noticed in the Introduction,* is caused by the tonic contraction of the muscles; it is independent of the nervous system, so that neither the section of the nerves, the removal of the brain, nor the state of hemiplegia, prevents its manifestation. It has been compared to the contraction of the fibrinous coagulum of the blood, and, like this, it does not cease till the commencement of putrefaction.†

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* Beclard, l. c. p. 576.

SECTION VI.

DEVELOPMENT OF THE MUSCULAR SYSTEM.

WHEN the embryo is first formed, this tissue cannot be distinguished from the cellular membrane with which it is confounded in a common gelatinous substance. The involuntary muscles are first developed, and afterwards the voluntary. At an early period after conception, a small point, *punctum saliens*, indicating the situation of the heart, may be distinguished by its pulsations, although no fibres are discoverable by the microscope during its first actions. Towards the second month, the muscles of the skeleton have distinct fibres; they present the appearance of viscid and yellowish layers; at the end of the third month, the tendons begin to be formed; during the fourth and fifth months the fibres become redder and firmer, and are more easily distinguished from the tendons; in the sixth month, although they are very soft, they are still more perfect. At the full period of gestation the muscles are formed, but they are soft, pale, and larger in proportion to their tendinous substance than in the adult. Some time after birth they become redder and stronger, although they remain during a long time, rounded and soft; they also contain more gelatine and less fibrin than when their organization is perfected. When the growth of the body is completed, the muscles acquire greater thickness, cohesion, and colour; these qualities are developed to more advantage, in proportion to the health of the individual, and to the exercise of the muscles. In the progress of years, the redness, cohesion, and force, gradually diminish, whilst the hardness increases; in old age the muscles become pale, yellow, and even livid.

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* See p. 103.

† Beclard, Anat. Gen. p. 577. A contrary opinion is supported by Sir A. Carlisle.

There is some uncertainty concerning the development of the muscular power in young animals. In the human fœtus no perceptible contractions occur in the voluntary muscles till towards the middle period of pregnancy; but the power of the heart is exerted at a much earlier stage. Bichat thinks that the muscles of the fœtus have an irritability, or, at least, a susceptibility to galvanic influence inferior to that of individuals who have respired. The experiments of Meckel, on the contrary, tend to prove that contraction is exercised with more energy in a young than in an old animal; they also shew that contractility remains a longer time after death in a new born animal than in the adult. Thus he could not excite the muscles of a full grown rat at the expiration of an hour and a half after death; whilst contractions were produced by the effect of contact alone in a rat killed immediately after birth, for the space of eight hours. During infancy the muscular movements are easily excited and performed with promptitude, but they are weak and of short continuance. In the adult the motions of the body are more perfect, and more powerful than in the child; they are also distinguished by their durability and precision. In old age the contractions become weak, slow, and uncertain, and, consequently, the movements of the body are imperfectly and difficultly performed.

The muscular system presents some differences which depend on the sex; *cæteris paribus*, the muscles are more rounded, weaker, less firm, and less powerful in the female than in the male; they enjoy, as in youth, a greater susceptibility to motion, but their action is weaker and less capable of being sustained.

PART SECOND.

SECTION I.

OF THE VOLUNTARY MUSCLES.

THE name of muscles is frequently restricted to these bodies which are distinguished by being the active organs of motion, and by being immediately under the controul of volition.

The voluntary muscles constitute a large proportion of the mass of the body, especially in those individuals who are engaged in laborious occupations. They are, in general, placed around the bones, and, consequently, towards the external surface; in some parts of the body they are situated more deeply, as in the mouth, chest, and abdomen.

Their number, which is very great, is liable to variation; this does not so much depend on any actual difference in the muscles themselves, as on the manner according to which they have been described by anatomists; some writers considering certain muscles to be composed of several fasciculi, which others have regarded as forming so many distinct muscles. Chaussier has admitted only three hundred and sixty-eight, whilst other writers extend the number to four hundred.

Each muscle of the human body has received a proper name, founded on some consideration or other connected with the organ. The nomenclature of this part of anatomy is so imperfect, and so many alterations have been made in it, that there is scarcely a muscle which has not more than one name, and some have received as many as ten or twelve.

Various circumstances have, at different times, regulated the application of names to muscles; a numerical order was observed, by some anatomists, to distinguish these organs, when several of them belonged to the same part, and produced the same kind of movement; as in the instance of the extensors of the thumb, of the interossei, &c., which are called first, second, third, &c. The muscles have been more commonly named from a combination of several circumstances; for example, according to the predominance of one or other of their dimensions, from their size, from their situation in certain regions of the body, or from their connexion with different organs. Thus there are the latissimus dorsi, longus colli, rectus capitis posticus major, vastus internus, anterior auris, &c. The relative position has very frequently influenced the names, hence the terms anterior, posterior, internal, external, superficial, deep, &c. The name is often derived from the use of the muscle, and from the part to which it is attached; this has given rise to the terms of levator, depressor, abductor, adductor, flexor, extensor, supinator, sphincter, &c. Many muscles are distinguished by their figure, as the deltoides, rhomboideus, trapezius, scalenus, orbicularis; others by the straightness or obliquity of their fibres, as the rectus abdominis, rectus oculi, obliquus oculi; some by the direction of the fibres, as cervicalis descendens, obliquus abdominis ascendens, transversalis perenei; a few are named from their mode of connexion with the tendons, such as the semi-tendinosus and digastricus; and others from the number of their origins, as the triceps and biceps.

Many attempts have been made to improve the nomenclature of the muscles by modern anatomists, especially by Chaussier and Dumas. The arrangement of the former, which is founded on the principle of naming the muscles according to the connexions of their two extremities, has many advantages, and is well calculated to facilitate the study of myology, because the name of each muscle conveys to the mind the most important points of its attachment. The terms of this anatomist are generally adopted in France. The nomenclature suggested by Dumas, is a modification and extension of Chaussier's principle; the names, according to this plan, being intended to express briefly all the points to which each muscle is attached. But, as it has been judiciously remarked, where the origins and insertions are numerous, the name that pretends to enumerate the whole must often run out to the length of a sentence.*

In the work of Dr. Barclay,† the vagueness, and, in many instances, the decided incorrectness of the expressions in common use amongst anatomists, are forcibly depicted; and he has suggested new terms founded on a scientific and determined basis, which would certainly, were they generally employed, introduce great clearness and precision into anatomical descriptions. But to effect so desirable an object, it is necessary that these terms should be adopted by common consent; for otherwise, they would only add to the confusion which already so much encumbers the study of anatomy.*

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* The reader may have some idea of the inconvenience that would result from the general employment of these names, by the following examples: *sus-spini-scapulo-trochiterien*, supra spinatus; *sterno-costo-clavio-humeral*, pectoralis major; *sus-optico-spheni-scleroticien*, levator oculi.

† Entitled a New Anatomical Nomenclature.

The voluntary muscles are usually disposed in pairs, but the following are single; the diaphragm, the sphincters of the mouth and anus, the arytenoideus transversalis, and generally the azygos uvulæ.

The muscles are distinguished according to their situation and connexion into those belonging to the skeleton, into those of the larynx, of the organs of the senses, and lastly of the skin. Several of the muscles of volition also belong to the orifices of the digestive, respiratory, genital, and urinary passages, where they are insensibly confounded with the internal muscles. A useful division of the muscles, in many respects analogous with that of the bones, is founded on the relative proportions which they present in their three dimensions. According to this arrangement they are divided into three classes: *the long*, *the wide*, *and the short*.

The long muscles are more numerous than those of the other divisions; they are almost entirely confined to the limbs, and are usually placed in strata, of which the superficial are composed of the longest muscles; whilst in the deeper layers the muscles are shorter, and are more fixed in their situation, in consequence of being closely attached to the bones.†

The broad muscles generally consist of thin but extensive planes of fibres, placed on the trunk; they occupy the exterior of the great cavities of the body, and in some instances, as in that of the abdomen, they constitute the larger part of their walls; whilst in others, they merely clothe the osseous parietes. Several of these organs extend from the trunk to the limbs, in which course they often become considerably elongated.

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* It may be considered a fortunate circumstance for English students, that the teachers of anatomy in this country are usually satisfied with employing the names which have long been established in common use. A continental writer, Dr. Schreger, is of a different opinion, as he is stated to have published a thick octavo volume to unravel these complicated synonymes.

† These circumstances explain the cause of the unequal retraction of the superficial and deep muscles, observed in an amputation.

In the third class the muscles have their three dimensions nearly equal; they are generally triangular or oblong in their form. They are, in proportion to their size, more powerful than those of the two preceding classes, and are, consequently, placed in those parts of the body where strength rather than extent of motion, is required; for example, around the temporo-maxillary articulation, the joints of the head with the vertebral column, of the foot, hand, &c.

Each of the voluntary muscles usually possesses a central part, called the *body* or *belly*, and two extremities, one of which is termed the head and the other the tail; the head is connected with some fixed point, which is regarded as the *origin* of the muscle; the lower end is attached to a more moveable part, which is considered as the *insertion.* This form is exemplified in several of the muscles of the limbs which are enlarged in the middle, owing to the disposition of the fleshy fibres, and contracted in the extremities, which are generally tendinous. The annular muscles, as the orbicularis oris, sphincter ani, &c., do not possess any tendinous structure; this observation also applies to several of the small muscles, as those of the lips and of the larynx.

The tendons,* which are usually placed at the two extremities of the muscles, are in most instances of unequal length; the one towards the origin being with a few exceptions, shorter than that towards the insertion; it frequently happens that there is only one tendon which is attached sometimes to one, sometimes to the other extremity. They are always much smaller than the muscles to which they are attached; this arrangement preserves the symmetry and form of the body, and also facilitates the complicated movements of its different parts.

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* See p. 359.

The fibres in the voluntary muscles are usually straight and parallel to each other; but they are sometimes radiated, as in the diaphragm, the pectoralis major, the genio-hyo-glossus, &c.; and occasionally they observe a circular course.

When all the fibres run obliquely in one direction towards the tendon, they form what are called the single or semi-penniform muscles (*musculi semi-pennati*); when the parallel fibres pass in two directions so as to meet in the centre, they produce the complete penniform muscles (*musculi pennati*). The rectus femoris is an instance of this disposition. There are some examples of the compound penniform muscles, which consist of two penniform bellies joined together; the gastrocnemius is of this order.

The direction of the entire muscle, which is described by drawing a line through its centre from one extremity to the other, is frequently different from that of the fibres. When the course of the muscle and of the fibres is exactly the same, the power of the former, which in this case is equal to the sum of the forces of all the fibres, is exercised in the line of its direction; but if the fibres do not correspond with the course of the muscle, or with each other, then the intensity and the direction of the force will vary according to the kind of deviation.

Some of the muscles are simple and distinct in their whole extent; whilst others are divided into several portions, either at their origin or at their insertion, or at both these points. There are examples of the former, in the semi-membranosus and gracilis. Amongst the latter or compound muscles, some have two or three distinct portions at their origin and a single insertion; such are the triceps extensor cubiti, the sterno-mastoideus, and the pectoralis major; others are single in their origin, and divided at their insertion, as the flexor and extensors of the toes. These divisions are occasionally so distinct, that certain muscles which are regarded by some anatomists as single, are described by others as forming several muscles; this is the case with the levator labii superioris alæque nasi, and the extensor digitorum manus. Again, the extensor of the leg is usually described as consisting of three separate muscles, viz. the two vasti and cruræus; whilst, by many authors, it is considered as one, called the triceps extensor cruris.

Some muscles are united to each other at their origin, as the biceps cruris and semi-tendinosus, and also the coraco-brachialis and biceps cubiti; others are joined at their insertion, as the latissimus dorsi and teres major, the different muscles of the lips, &c. In some regions of the body, as in the sole of the foot, and the deep part of the back, the different muscles are so much confounded together that it is difficult, and in some subjects impossible, to distinguish them from each other.

The muscles of volition are provided with certain appendages consisting of the aponeuroses and tendinous sheaths,* which increase their power and facilitate their action; the former, by supporting the fibres in their situation and by preventing any displacement during their contraction; the latter, by fixing the tendons and by allowing them at the same time to play freely within the synovial bursæ.

SECTION II.

MECHANISM OF MUSCULAR MOTION.

I HAVE hitherto deferred speaking of the mechanism which is displayed in the production of animal motion, because the following observations almost exclusively apply to the voluntary muscles.

The muscles are divided according to the kind of movement they produce, into *associates* and *antagonists;* the former act together and, by their combination, they cause the same kind of motion; the latter on the contrary, act in an inverse sense to each other, and thus produce dissimilar movements.

The various motions of the body, with the exception of those which are very simple, are accomplished by the combined action of two or more muscles. In many instances, muscles which are opposed to each other in their single actions, are associated to produce an intermediate movement. In all these cases there is a composition of forces, each muscle losing a portion of its power; thus if the abductor and levator oculi contract but there is a compensation in the velocity and extent of motion which are acquired.

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* See p. 352, *et seq.*

The first kind of lever, in which the fulcrum is placed in the centre, is employed in certain movements requiring great force; there is an example of this in the action of the extensor muscles of the spine, which are inserted behind the fulcrum, whilst the part to be moved or the weight is placed before it. The second species of lever is but rarely used in muscular action; several instances, however, might be adduced in which the weight or resistance is situated between the power and the fulcrum; thus, in depressing the lower jaw, the fulcrum corresponds to the temporo-maxillary articulation, the power is represented by the chin and the weight in the bone between these points: again, in raising the body on the toes, the fulcrum is at the end of the foot, the power is placed in the heel, and the resistance in the joint of the ankle.

Besides the loss of power occasioned by the nature of the lever which is generally employed, and that caused by the association of the muscular contractions, the following circumstances will also produce the same effect. 1. The mode in which the muscles are inserted into the bones, and the fibres into the tendons. 2. The equal division of the muscular effort on the two points of attachment. 3. The resistance of the tonic contraction of the antagonist muscles. 4. The friction of the muscle and its tendon on the surrounding parts.

1. The muscular fibres are usually placed so as to act obliquely; this arrangement causes a loss of power; but what is lost in power is gained in the saving of the

quantity of contraction; for it may be demonstrated, that a given extent of motion can be produced by a smaller quantity of contraction if oblique fibres are used than when straight ones are employed.* Another great source of the loss of power is, that the tendon is generally inserted into the bone at an acute angle, whereas, in order that the power should have operated in the most advantageous manner, it ought to have acted on the lever in a perpendicular direction.

2. As the fibres contract from their extremities towards the centre, it is evident that half the effort of the muscle is expended on the point which is fixed; thus, if the deltoid exerts a power equal to one hundred pounds, only half, or fifty pounds, will be employed in raising the arm, the other half being exerted on the scapula. This fact shews the necessity of every muscle having a *fixed point* during its contraction, for if both extremities were equally moveable, they would approach each other when the fibres were shortened. In order to prevent this event taking place, almost every motion is a compound one; for example, before the deltoid can effectually raise the arm, it is necessary that the trapezius, rhomboidei, &c. should secure and fix the scapula.

3. A third cause of the loss of power depends on the disposition of the muscular system, which is such that in general one set of muscles cannot act without experiencing the resistance arising from the tonic contraction of the antagonists.

4. Another circumstance unfavourable to muscular

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* A very interesting account of the mechanism of muscular action will be found in Dr. Bostock's Elem. Sys. of Phy. vol. i. p. 183. The effects of the oblique direction of the muscles are considered by Dr. Monro, 2dus. See Outlines of Anat. vol. i. p. 105.

action, is the rubbing of the tendons and of the articulations against the adjacent parts. This loss of power is considerable in those instances in which the muscle passes over several joints before it is inserted; the laxity of the cellular texture, and the provision of the bursæ mucosæ, tend, however, to diminish the effects of friction.

All these mechanical imperfections are productive of an enormous sacrifice of power, so that it has been calculated the deltoid employs a force equal to two thousand five hundred and sixty-eight pounds to overcome a resistance of fifty pounds.

Notwithstanding so many circumstances exert an unfavourable influence on the action of the muscles, there are some which have a contrary effect. In the first place, it may be noticed, that the angle at which the muscle is inserted, is enlarged by the swelling of the extremity of the bone, by the projection of the different processes, and by the existence of some particular bones, such as the patellæ and ossa sesamoidea, which change the direction of the muscles previous to their insertion; the same result is also produced by the pullies over which certain tendons are reflected. Again, it frequently happens that the angle of insertion is increased during the contraction of a muscle; we observe this in the action of the flexors of the leg, which become more perpendicular to the bones, and consequently more powerful, as the tibia and fibula are drawn backwards.

In conclusion, it must be remarked, that the mechanism of the muscular system is equally perfect with all the other works of nature. It is true that power is sacrificed by the employment of the third kind of lever by the combination of the muscles, and by the oblique insertion of the fibres, and of the tendons; but this loss is amply counterbalanced by the extent and velocity of motion which are thus gained, and also by the preservation of the form and symmetry of the body.

The muscles of volition are capable of exerting themselves in an extraordinary manner, whenever circumstances render such exertion necessary. In these instances, very forcible muscular contractions produce what we term *efforts*, which are destined to overcome any external resistance, or to perform some laborious function; they are required, for example, in sustaining a heavy burden, in lifting a great weight, in difficult expulsion of the fæces, in parturition, &c. In all powerful exertions, a great number of muscles are called into action; the process of respiration is greatly excited; and the energy of the nervous system is, for the time, considerably increased. As a necessary preparation for every muscular effort, the chest must be fixed; this is effected by taking a full and deep inspiration, so as to distend the thorax, the lower part of which is rendered immovable by the combined action of the diaphragm and abdominal muscles, and at the same time the glottis is closed so as to prevent the escape of the air.* The parietes of the thoracic cavity being thus secured, it follows that the muscles proceeding from it will act on the limbs in which they are inserted, with an undivided force. Whilst the effort continues, the inspirations rapidly succeed each other, by means of which the numerous muscles that are employed, have an interval of rest, and the venous blood, the flow of which is in some degree obstructed during the fixed state of the chest, passes towards the heart, in order to be decarbonised. This hurried respiration induces such distress, that after a longer or shorter period, the effort must be discontinued. Those individuals who have capacious and sound lungs, and who have acquired, by practice and training, the power of repeatedly suspending their respiration, are capable of persevering in muscular exertion in a very astonishing manner. At the same time that the respiratory muscles are in action, those of the face partake in the effort, and give a strong expression to the countenance. The blood is also determined towards the head, a phenomenon which principally depends on the impediment offered to the venous circulation.

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* The experiments of M. Bourdon prove that the closure of the glottis is indispensable in the production of any effort of the muscles: he made an opening in the windpipe of a dog that had been in the habit of jumping and tumbling when bidden; after this operation, the animal was no longer able to make any similar efforts, though evidently willing to do so; but on closing the aperture, by drawing the edges of the wound together, the lost power was instantly restored. See Recherches sur le Mécanisme de la Respiration et de la Circulation du Sang.

PART THIRD.

SECTION I.

OF THE INVOLUNTARY MUSCLES.

THESE muscles have not been distinguished like those of the former class by any particular appellations; they are only known by the names of the organs which they contribute to form. They consist of, 1. The heart. 2. The muscular tunic of the alimentary canal. 3. The muscular coat of the uterus. 4. The fibres belonging to the trachea and bronchi. 5. The iris. 6. The small muscles of the tympanum. The muscles of the urethra, and most of the sphincters, are analogous in some respects with the preceding; they are in fact intermediate to the two classes of muscles, and by their situation and functions, they share in the characters of both sets. There are certain reservoirs and canals in which we must presume contractions take place, although no proper muscular structure can be detected. This observation particularly applies to the blood-vessels, the gall bladder, and to some excretory ducts, as those of the liver, of the kidney, and of the testis; it is difficult to explain the manner in which these canals transmit their contents, unless their contractile power is admitted. Does there exist any structure independently of the muscular, which is susceptible of being excited to contraction by the application of a stimulant? This is a very interesting question, but it is one which we have no sufficient data to determine.

The involuntary muscles, whose bulk is inconsiderable, are placed deeply in the interior of the body; and, with a few exceptions, they are situated beneath the mucous membrane, where they assist in forming certain cavities, which have in general a cylindrical form. They consist of fibres arranged in layers, or in irregular fasciculi, which interlace with each other. In the whole extent of the alimentary canal, there are circular and longitudinal fibres disposed in two distinct layers; the former of which are usually the strongest, the latter are occasionally, as in the large intestine, collected into fasciculi. The same arrangement is observed, but in an imperfect manner, in the air passages. In the reservoirs, as the heart, the stomach, and also in the uterus, the fibres are placed in irregular bundles, which cross each other in all directions.

These muscles vary so much in their colour, in their cohesion, and in their disposition, that it is in some instances difficult to determine what parts ought to be admitted as belonging to this division of the muscular system. The dispute concerning the muscularity of the uterus is well known; and, although this question may be considered as being decided in the affirmative, there is another of much greater importance, on which the opinions of the best anatomists of the present day are divided: I allude to the structure of the middle tunic of the vascular system.*

The colour of the involuntary muscles is greyish red; but in the heart the fibres are of a deep red, whilst in the uterus they are pale, and even yellow.

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* See pp. 272-277.

The structure of these bodies, with a few exceptions, is essentially the same as that of the muscles of volition. The fibres are distinguished by their irregular disposition, and by their mutual interlacement; they are also short and interrupted in their course. The blood-vessels are thought to be more plentiful than in the preceding class. The cellular tissue, on the contrary, is not so abundant; it is more condensed, and does not form very apparent partitions between the fasciculi of the fibres. With the exception of the carneæ columnæ of the heart, the muscles of this class do not possess any tendons, although some anatomists have erroneously described them in the stomach, intestines, and uterus.

Section II.

PROPERTIES OF THE INVOLUNTARY MUSCLES.

Having, in the first part of this chapter, pointed out the most important faculties of the muscular system in general, I shall in this place only notice some peculiarities which are exhibited in the involuntary organs.

The greater number of the physical properties are more striking in their muscles of this, than in those of the preceding class. Thus their fibres are more extensible, more cohesive, and more elastic; and in virtue of the latter power, they possess a greater degree of tonic contraction.

The principal differences, however, relate to the vital properties, and particularly to the manner in which contractility is excited.

In the state of health, the involuntary muscles are generally considered as being insensible, and in the ordinary acceptation of that term, this opinion is correct; for it has been ascertained, that if the heart be exposed during life in the human subject, it may be touched almost without the consciousness of the individual. But, as I have had occasion frequently to remark, it by no means follows, because the mind does not perceive the impression made on any organ, that therefore the organ is insensible. On the contrary, it is known that the iris, the heart, the fibrous coat of the stomach, &c. are capable of receiving the impression of light, of blood, food, &c. which act as stimulants to excite their contraction.

The contractile power of the hollow muscles, which is essentially the same as that of the external muscles, is remarkable in consequence of the manner in which it is excited. Volition, which is the natural stimulus to the latter class of organs, is never capable of determining the contraction of the former; thus, for example, we can at pleasure excite the action of the muscles of the arm, but no effort of the will can produce any alteration in the movement of the heart, or in peristaltic contraction of the intestine.* Again, the brain and the nerves which are essential to the exercise of voluntary motion, are not necessary to the production of involuntary action; for this is manifested in those fœtuses which have been born alive without either brain or spinal cord; and also, in the case of the heart, after all communication between it and the encephalon has been cut off by the division of its nerves. These facts prove that under ordinary circumstances, neither volition nor the influence of the nervous system, is essential to the action of the heart, or to that of the other involuntary muscles. It may then be asked what determines these organs to contract. In answer to which query it may be stated, that they are excited by local and peculiar agents—the heart by the blood—the stomach by the food—and the iris by light.*

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* Although the will has usually so little influence on the action of the involuntary muscles, yet there are instances of a contrary nature. Some individuals have the power of rumination, which is a process requiring an act of the will. A still more remarkable case is related by Dr. Cheyne of an officer residing at Bath, who had the power of entirely stopping the contractions of the heart; and a similar example is mentioned by Ribes.

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* Notwithstanding that in the quiet state of the body, the involuntary motions proceed independently of the nervous system, it is necessary to repeat what was stated in a preceding page, that they may be influenced by the passions of the mind, and also by mechanical and chemical agents applied to the brain and spinal cord. If it be objected that this statement implies a contradiction, we may reply with Le Gallois and Philip that two facts well ascertained, however inconsistent they may seem, do not overturn each other, but only prove the imperfection of our knowledge.

CHAPTER ELEVENTH.

OF THE NERVOUS SYSTEM.

THIS system in the human species consists: 1. Of a large mass called the brain. 2. Of the spinal cord.[*] 3. Of numerous cords termed nerves. 4. Of certain enlargements or knots, which are distinguished by the name of ganglions. These bodies are the essential and exclusive organs of sensibility; a property which produces most important and diversified results in the animal economy.

The ancients, under the same name, confounded the nerves with the ligaments, the tendons, and even with the vessels. Although some discoveries were made previous to his time, yet Galen was the first anatomist who satisfactorily distinguished the nerves from the tendons and ligaments, by giving to the latter separate and characteristic appellations. This celebrated man also ascertained that the nerves are medullary in the interior, and membranous on the exterior, and in this manner he established their connexion with the spinal cord and the brain. He further observed, in opposition to the existing opinions, that the spinal marrow was subservient to the brain; and he is likewise regarded by many authorities, as the discoverer of the ganglions. Subsequent to the time of Galen, the science of anatomy was nearly stationary, and continued so during many centuries, so that it was not until the revival of letters that any progress was made in the knowledge of the nervous system. At this period the structure of the body was cultivated with great success; although, in consequence of the too indiscriminate deference which was paid to the opinions of the ancients, many errors were revived; and these being tenaciously adhered to by succeeding anatomists, produced an injurious influence which has extended even to the present day. Within the last few years, however, a surprising progress has been made in this branch of science. By the assistance of comparative anatomy, the real nature of many parts of the nervous system, and the relations existing between them, have been satisfactorily explained; whilst by observations on man, and experiments on the inferior animals, their functions have been greatly elucidated.

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[*] The brain and the spinal cord are described by many anatomists of the present day, under the term of *encephalon:* other writers restrict the use of this word in accordance with its derivation, and apply it only to those parts of the system that are lodged within the head.

The origin and successive development of this system, have been traced from the most simple to the most complicated animals; and this investigation has proved that there are no organs which exhibit in their formation, so perfect a gradation from simple to compound as those under consideration.

The lowest animals, the infusory animalculæ, appear to possess no nervous system, the first traces of it being perceived in some of the polypi, as the hydra, under the form of microscopical particles which are disseminated through the substance of their bodies. In all the other classes of the invertebrated animals, the system may be described as consisting essentially of swellings or ganglions which vary in magnitude, and of cords or nerves connected with them. The ganglia and filaments are first distinguished in the radiata, and especially in the asteriæ; in each of these animals the central organ consists of a ring of white nervous matter* surrounding the mouth, or orifice of the stomach, and giving off delicate threads, which are distributed in a radiating manner to their soft and contractile substance.

In the articulated animals the nervous system consists of two cords, passing nearly in a parallel direction from one to the other extremity of the body; on each cord a small ganglion or nodule is formed opposite to each of the segments into which the animal is divided.

Anatomists are not agreed on the nature of the filaments which proceed from these ganglions; some regarding them as being analogous to the nerves of the sympathetic system, whilst others compare them to those of the spinal cord. The latter theory is supported by Mr. Bell, who observes, that the nerves of the leech, or worm, bestow sensibility, and also regulate and combine all the voluntary motions of these animals.† Now, as the same properties in the vertebrata are connected with the spinal cord, and with the nerves arising from it, we may conclude that these are the parts which correspond with the nervous system of the invertebrated animals.‡

In some of the mollusca there is a distinct rudiment of a brain, which is enclosed in an imperfect and cartilaginous cranium; this is an evident indication of a proper nervous centre for regulating the organs of sensation and of motion.

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* Cuvier was the first who ascertained that the nervous system of the star-fish is composed of white matter without any intermixture of the grey substance.

† Philos. Trans. 1823, p. 305. Exposition of the Nerves, p. 41.

‡ Mayo's Outlines of Physiology, p. 279.

The nervous system of the vertebrated animals consists of a central mass, which is composed of a body called *spinal cord*, and of an enlargement which is added to its superior extremity, under the name of *brain*. The former structure gives attachment to a number of *nerves*, regularly disposed in pairs on the two sides of the median plane of the body, each of which possesses, at its central extremity, a swelling or ganglion. Lastly, there exists on the fore part of the vertebral column, two ganglionic cords, named the *great sympathetic nerves*.

These component parts exhibit many varieties in the four classes of the vertebrated animals, which have been traced with great minuteness by several modern anatomists.*

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* Those who take an interest in this important branch of comparative anatomy, will find ample details in the writings of Serres, Tiedemann, Spurzheim and Desmoulins.

PART FIRST.

SECTION I.

OF THE NERVOUS SYSTEM IN GENERAL.

THE different parts which compose this system, although endowed with distinct powers, are united with each other in such a manner that they constitute a connected whole. Anatomists, from the time of Galen downwards, have very generally regarded the brain as the sole origin and centre of this system; and in accordance with this idea, the spinal cord and the nerves were described as prolongations of the cerebral organ, and even the great sympathetic was viewed in the same light. The researches of comparative anatomy have proved the error of this opinion; for it is now well known that the nerves and the spinal cord are formed in the inferior animals and in the embryo of the higher classes, anterior to the brain. Numerous examples are also recorded of acephalous monsters in which, although the brain was deficient, the nerves and the spinal cord were perfectly formed.

Many physiologists have more recently supposed that the nervous system possesses more than one centre. Thus Dr. J. Johnstone, towards the close of the last century, pointed out the distinction between the nerves of voluntary and involuntary parts; the former being derived from the brain and spinal cord, and the latter from the ganglions.* This doctrine was subsequently embraced by Bichat, who states that the nervous system ought to be divided into two parts, essentially distinct from each other, and having for their principal centres, one the brain and its dependencies, and the other the ganglions.

Some modern writers have supposed that there are several nervous centres; such is the opinion of Cuvier and De Blainville; the latter considers that the nervous system ought to be divided into as many parts as there are principal functions. Drs. Gall and Spurzheim contend that the nervous system is not an unit, but that it consists of many essentially different parts, which have their own individual origins, and which are in mutual communication.

The numerous experiments which have been performed on living animals, prove that particular parts of the nervous system are allotted to the exercise of particular functions; so that no individual organ can be considered as the source whence all the other structures are derived, because each part of the system may have, in a certain degree, an independent existence. In the higher classes of animals, however, and especially in man, the brain is so largely developed that it has a most striking influence on the other nervous masses, and the whole of these are so intimately connected that they cannot be regarded in an insulated manner.

Although the investigations of modern physiologists have shewn, that the nervous system consists of an aggregation of many organs, which respectively exercise different functions, it is still very difficult to make any classification of them that shall be free from defects. The most comprehensive arrangement is that which is founded on the division of the functions into two great classes; viz. the animal functions, or those which are attended with consciousness; and the organic functions, or those of which the individual is not conscious. The nervous organs belonging to the first of these classes, consist of the spinal cord, the brain, and the nerves connected with them; those of the second are the ganglia of the great sympathetic, and the nerves attached to them. It is necessary to state that there are many exceptions to this division; thus some of the nerves of the medulla oblongata furnish branches to the organs of the vegetative functions; whilst the sympathetic sends filaments to the muscles of volition.

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* The honour of this distinction has been generally attributed to Bichat; but he has no just claim to it, as the essay of Dr. Johnstone, containing his opinions concerning the use of the ganglions, was published in this country, and translated into the French language, several years before the justly celebrated works of Bichat made their appearance.

In proceeding with the consideration of these two divisions, I shall, in the first instance, describe the properties that they share in common, and afterwards point out the peculiarities by which each is distinguished.

The nervous system exhibits in a striking manner the symmetrical form; this disposition is observed in the central and in the peripheral organs, but in a more perfect degree in the former than in the latter: the symmetry is also more decided in the spinal cord than in the brain, and in the interior of both these organs than on the external surface; thus the convolutions of the cerebrum and the layers of the cerebellum are more subject to deviations of form on the two sides of the body than the more internal parts. The nerves proceeding from the encephalon, the cerebral and spinal, are all symmetrical, with the exception of the pneumo-gastric, which are distributed to irregular organs. The parts which compose the system of the sympathetic nerves, are very irregular in their origin, and especially in their termination. With these exceptions, the resemblance of the lateral halves is so great in almost the whole extent of the nervous system, that it is often impossible to perceive the least difference between them, with respect to situation, form, and size.

The great nervous masses are all placed deeply in the trunk of the body, so as to be defended from external violence; some of them, as the brain and spinal cord, are still further protected by being enclosed within strong osseous cavities. The principal nerves are also removed from the surface, and are lodged in the most secure situations; their terminal extremities being the only parts that are exposed to the contact of surrounding bodies.

COMMUNICATIONS OF THE NERVOUS SYSTEM.

The various parts of this system are intimately connected with each other, and in this manner the mutual influence or sympathy which is observed between their functions, is established. The structures which form the nervous communications, are the following: 1. Those which are placed between the lateral halves of the symmetrical organs. 2. Those which connect the nervous masses of the same side of the body.

I shall describe these structures in a connected and succinct manner, because I believe their nature to be essentially the same in whatever part of the system they may be situated.

The first species of communication is principally met with in the spinal cord and encephalon, but it also exists between some of the nerves, especially those of the sympathetic.

The lateral columns of the spinal cord* are united by numerous fibres, which may be seen running transversely at the bottom of the anterior median fissure, and longitudinally in the posterior furrow. The lateral parts of the medulla oblongata are connected in a similar manner, except in the place where the decussation of the anterior pyramidal bodies occurs. This intercrossing has been denied by many anatomists; there is, however, no doubt of its existence, and of its serving to bring into communication several of the cerebral masses of one side of the body with an opposite portion of the spinal cord.

The different bodies of the cerebellum and of the cerebrum placed on the sides of the median plane, are connected with each other by many transverse fibres, which produce the *commissures;* several of these, such as the corpus callosum, anterior and posterior commissures, have been long known, but we are especially indebted to the researches of Gall, and of his pupil and colleague, Spurzheim, for an acquaintance with the real nature and relations of these important organs.

The nerves of the cerebro-spinal axis do not communicate with each other across the median plane; but there are exceptions in the optic nerves, and occasionally in the pathetic and auditory nerves, which are united towards their origins; and also in the pneumogastric nerves, which are connected in their course and termination. On the contrary, the nervous cords which belong to the sympathetic, form free connexions across the median plane; there are remarkable examples of this disposition in the cardiac and solar plexuses.

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* This body will be described in the second part of this chapter.

The communications, of the second kind, or those between the nervous masses of the same side of the body, are very numerous and complicated. Those of the encephalon have been unravelled and traced with most extraordinary skill and success, by Gall. This excellent anatomist has demonstrated the uninterrupted course of the fibres of the spinal cord, and of the medulla oblongata: he has most satisfactorily proved, that some of the fasciculi of the latter organ are continued through the substance of the cerebellum, and ultimately to the laminæ on its surface; that others pass through the pons varolii, the thalami nervorum opticorum, and the corpora striata, till they at length reach the convolutions on the exterior of the cerebrum. There are many other connexions between the individual parts of the brain, but the consideration of them falls within the province of descriptive anatomy.

The nerves belonging to the same class communicate together; thus the different motor nerves are connected with each other, and the same may be said of the sensitive nerves. There are also connexions between nerves that exercise distinct functions. The spinal nerves, which are composed of sentient and motor fibres, communicate with each other; as in the plexuses of the arm-pit and loins. The connexion between the two classes of nerves is even more apparent in the union of the ophthalmic and superior maxillary divisions of the fifth pair, which are of the sentient order, with the branches of the portio dura of the seventh pair, which is a nerve of motion. Besides these large connexions, it is thought, by many anatomists, that the filaments of the individual nervous cords interlace with each other.

There is some doubt concerning the nature of the communication within the plexuses. Is there an actual intermixture of the nervous matter belonging to the different fibres?

We learn from Monro, that "in the plexuses, the fibres of the different trunks are intermixed, and that every nerve under the plexus consists of fibres of all the nerves, which are tied together above its origin from the plexus."

Mr. Bell, who has paid great attention to this subject, states, that the several motor and sentient filaments retain their respective offices from one extremity to the other, and that they are as distinct from each other in their whole course and distribution, as they are at their origins in the spinal cord. Occasionally, however, two filaments of a different kind are combined so as to bestow a double power on the nerve thus constituted.

This distinguished physiologist thinks farther, that in a plexus the motor nerves interchange branches with each other, by which means the actions of the numerous muscles supplied by these nerves, are combined so as to produce the varied motions of the limbs.

We may conclude, from these observations, that although in a plexus there is a free connexion between the nervous branches, they principally relate to those of the motor character; and that where two branches differently endowed do communicate, each still retains its proper and distinct office.

The last communication that requires to be noticed is one which has considerable influence on the phenomena of the nervous functions; I allude to the connexions which exist between the nerves of the cerebro-spinal axis and those of the great sympathetic. These are usually accomplished by means of ganglions; and it is in this manner that the cerebral and spinal nerves communicate with the nerves of the heart, of the intestines, &c. In some instances the union is established by plexus, as where the branches of the eighth pair join with the cardiac and solar plexuses.

Section II.

ORGANIZATION.

The different parts of the nervous system are formed of two substances, which are distinguished by their colour, situation, and composition. One of these materials is distinguished by the name of the *cineritious* or *cortical substance;* but both these terms have been injudiciously chosen; in the first place, because this matter varies in its appearance from nearly a white shade to a red, yellowish, or even black colour; and in the second place, because it is occasionally situated in the interior, and, consequently, cannot form a cortex or bark. The second substance has been called the *medullary matter*, a term equally objectionable as the preceding; as it has been proved to consist of fibres, it would be most appropriate to call it the fibrous substance.

The variations in the colour of the grey matter have probably given rise to the contradictions observed in authors, as to which of the two substances first appears in the development of the nervous system. Gall contends that the grey pulpy substance is formed prior to the white; that it is always found in those places where the white fibres become more numerous; and lastly, that it receives a great number of blood-vessels. From these circumstances, Drs. Gall and Spurzheim suppose that the pulpy matter is the matrix of the nerves, and that it nourishes the fibrous substance. An opinion, opposed to this, has been advanced by several most acute anatomists; thus, it is stated by Tiedemann, that the fibrous matter of the spinal cord is first formed; he admits, however, that the grey substance is accumulated in great quantity in those parts of the cord from which the large nerves proceed, and that it augments the nervous energy.* The priority of the appearance of the grey matter is also denied by Serres;† but he states, subsequently, that a greyish fluid constitutes the primitive state of the spinal cord. We have already alluded to the fact discovered by Cuvier, of the nervous system of the asteriæ being entirely composed of white matter; and it is also stated by Desmoulins, that in fishes, and in many reptiles, the spinal cord does not exhibit any grey matter.

In answer to these objections, it has been observed, that the preceding anatomists have paid more attention to the colour of the so called grey substance, than to its essential properties of pulpiness and vascularity; and that the important point to be determined is, whether the existence of a gelatinous and greyish substance is a necessary antecedent to the formation of the white fibres. The researches that have been made concerning the development of the brain and spinal cord in the embryo of the human subject and of animals, prove, that these organs are formed in the first instance of a homogeneous reddish white matter, in which it is impossible to distinguish between the cortical and medullary substances; but that at a later period the two substances become evident.

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* Sir E. Home attaches great importance to the grey substance of the brain, regarding it as the seat of memory. Phil. Trans. 1821.

† Anat. Comparée du Cerveau. Preface, p. 37.

The grey substance is soft and apparently without fibres; when it is divided, its surface presents a number of red points and striæ. The opinions of anatomists are not decided with respect to its intimate structure. Some have supposed that it was formed of small follicles; whilst others regard it as a tissue of blood-vessels; it has been proved, however, by fine injections, that there is a peculiar substance distinct from the vessels, although the latter are very numerous. The grey matter becomes soft, and swells a little by being placed in water; it also loses a great part of its colour; it is hardened and rendered whitish by the action of acids, alcohol, and corrosive sublimate; it is also said to become fibrous.

This substance is never met with in an isolated state; it is always in connexion with the fibrous matter. It is found in large quantity on the external surface of the cerebrum and cerebellum; in the striated bodies, in the optic thalami, and in the quadrigeminal bodies; also, in the interior of the cerebellum, of the crura cerebri, of the pons varolii, of the medulla oblongata, and of the medulla spinalis; it is likewise observed in the ganglions. The nerves are generally supposed to consist of the white substance; but it is said by Monro,* that they are of a cineritious colour, and Gall states that the grey substance accompanies the nerves in their course.†

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* Obs. on the Nervous System, p. 38.

† Recherches sur le Système Nerveux, pp. 66, 81.

The white or medullary nervous substance is essentially fibrous. In many parts of the system the fibres are so distinct that they are visible without any artificial preparation; they are also readily seen by scraping any portion of the brain. In order, however, to demonstrate the fibres satisfactorily, it is necessary to harden them by a prolonged maceration in alcohol, or by the action of diluted nitric or muriatic acid; the same effect may also be produced by placing a portion of brain in a solution of the oxymuriate of mercury, or for a few minutes in boiling oil. This fibrous substance has long been known to anatomists; but it is only in the present day that the existence of fibres in all parts of it has been generally admitted. The size of the nervous fibres appears to vary in the brain, in the spinal cord, and in the nerves; their consistency is also liable to variation. The researches of modern anatomists, and particularly those of Gall, have ascertained the important fact of the continuity of the fibres in all parts of the nervous system. The white substance acquires a yellowish colour and a horny appearance when it has been dried; if it be cut in very thin slices it becomes semi-transparent; it regains its colour and opacity when it is placed in water.

The minute structure of the grey and fibrous substances has been carefully examined, with the assistance of the microscope, but without leading to any very satisfactory results. The greater number of those who have undertaken observations of this kind have concluded, that the nervous matter, whether pulpy or fibrous, is composed of minute globules, which are connected together by a viscid and transparent substance.

The observations of Mr. Bauer have commanded great attention in this country, and on the Continent, in consequence of the skill with which they were conducted, and the excellence of the instruments employed. According to the latest of these researches, the nervous substance is composed of globules, which are disposed in lines, so as to give the brain its fibrous appearance; their diameter varies from $\frac{1}{2400}$ to $\frac{1}{4000}$ of an inch, the predominant size being $\frac{1}{3200}$; they are larger and more numerous in the medullary than in the grey matter, which presents but few distinct fibres.* Subsequent to the investigations of Mr. Bauer, some observations have been published in Paris, by M. Milne Edwards. They agree with the preceding account, except that the globules are stated to be of the same size in the brain and nerves, in the four classes of vertebrated animals.

Dr. Hodgkin and Mr. Lister have not been able to detect any globular texture in the nerves, or even in the brain; in the latter organ they perceived a multitude of very small particles, irregular in their form and size, and which they think are more dependent on the disintegration than on the organization of the nervous substance. They consider that Dr. Edwards was deceived by the imperfection of his instruments.

In examining thin slices of the brain I have perceived a great number of rounded corpuscles; but, as these particles did not exhibit a fibrous arrangement, it is doubtful if they ought not to be referred to the cause suggested by Dr. Hodgkin. In the nerves, fibres are distinct which pass in a longitudinal and rather undulating manner. I could not distinguish any globules in the fibres, although a few were seen irregularly interspersed between them; it was impossible to decide whether these globules consisted of nervous matter, or of some animal fluid.

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* These particles, according to Sir E. Home, are connected together by a transparent and gelatinous substance, which varies in quantity in the different parts of the brain. He conceives that this fluid acts a most important part in the operations of the nervous system, and that even the communication of sensation and volition depends, more or less, upon it. *Phil. Trans.* 1821, p. 32.

The nervous system receives a very ample supply of arterial blood, which is indispensable to the exercise of its functions. The great quantity of blood sent to the brain has attracted the notice of anatomists, and attempts have been made to ascertain its proportion to that which circulates in the other parts of the body. Haller calculated that one fifth of the blood entering the aorta, is carried to the head. This estimate is thought by Monro to exceed the truth; he concludes, however, that one tenth part circulates within the head, which he says is nearly four times more than is distributed in the other divisions of the aortic system, as the weight of the encephalon is about one-fortieth part of the weight of the whole body. The veins of the brain and spinal cord exhibit several peculiarities, which relate to their structure, and to the manner of their arrangement. Nothing is satisfactorily known of the lymphatic vessels in the nervous system; the brain has been minutely examined with the hope of discovering them, but without success; a few trunks only have been detected in the dura mater and pia mater. We may conclude, however, from analogy and the effects of disease, that there are in the encephalon as elsewhere, appropriate agents of absorption. Some lymphatics are occasionally perceptible on the surface of the largest nerves.

The different organs belonging to the nervous system are enveloped in certain membranes which vary in their structure and number. The brain and the spinal cord possess three distinct coverings; the dura mater, the tunica arachnoides, and the pia mater; the nerves, on the contrary, have only one tunic, which has been appropriately named the *neurilema*.

The *dura mater* is a strong and fibrous membrane,[*] which constitutes the internal periosteum of the skull; it forms certain partitions which divide the hemispheres of the cerebrum and of the cerebellum, and thus prevent their compression in the various movements of the head. The vertebral portion of the dura mater only loosely surrounds the spinal cord, in order to admit of those extensive and complicated motions which are performed between the vertebræ.

The *tunica arachnoides*[†] is a serous membrane which lines the inner surface of the preceding structure, and also covers the brain and spinal cord. The arachnoid membrane secretes a serous fluid, which has been generally considered by physiologists to exist in a state of vapour during health. It has, however, been discovered by M. Magendie, that an aqueous fluid is always present in living and healthy animals on the surface of the brain and spinal cord, and also in the ventricles of the former. It appears to have an important relation to these organs, for the sudden loss of it occasions dulness and immobility; in the course of four and twenty hours the water being reproduced, the stupor was observed to disappear.

The most important membrane, and, indeed, the only one that is essential to the nervous structure, is that which is called *pia mater*, where it is connected with the encephalon and spinal cord, and *neurilema*, when it covers the nerves.

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[*] See p. 356.

[†] See p. 164.

Many anatomists regard the pia mater of the brain as being distinct from the vascular envelope of the spinal cord, and both, as different textures from the membrane of the nerves. It appears to me, however, that these coverings are merely portions of the same structure, modified in their density and vascularity according to the exposure, mobility, or size of the organs with which they are connected. It is well known that the membrane of the spinal cord and the neurilema of the cranial nerves are continuous with the pia mater of the base of the brain, and that, in a similar manner, the covering of the vertebral nerves is prolonged from that belonging to the medulla spinalis. The difference in the appearance of these membranes is not in itself a sufficient reason to deny the identity of their organization; for there are many parts that exhibit more striking diversities, which undoubtedly belong to the same class of organs; *ex. gr.* the peritoneum of the loins, and the arachnoid tunic of the ventricles.

The investing membrane sends various processes between the component parts of the organs which it surrounds; thus in the encephalon it sinks into the fissures between the lobes and convolutions of the cerebrum, and into those of the lobes and layers of the cerebellum; in the spinal cord it enters the abdominal and dorsal furrows; and in the nerves it penetrates between their fasciculi and fibres. This nutritious membrane of the nervous system consists of blood-vessels and cellular tissue; the existence of the latter, in the pia mater, has been denied by Dr. Gordon, who says, that after a minute injection, it is difficult to perceive any thing in it but blood-vessels.

Section III.

CHEMICAL COMPOSITION.

It has been ascertained, that the nervous substance is a peculiar chemical compound, unlike any of the other constituents of the body. The following is the analysis of the human brain, according to Vauquelin.

Water	80·00
Albumen	7·00
A white fat	4·53
A reddish brown fat . .	0·70
Osmazome	1·12
Phosphorus	1·50
Phosphates of potash, lime, and magnesia, and muriate of soda	5·15
	100·00

The spinal cord and the nerves have the same constituent principles as the brain, but there is some slight difference in their proportions.

SECTION IV.

PROPERTIES OF THE NERVOUS SYSTEM.

THE vital properties of the nervous system bestow on the animal kingdom a mode of existence which is totally wanting in plants; in virtue of these faculties every animal* possesses: 1. A consciousness of its own existence. 2. A capability of receiving impressions from surrounding bodies. 3. A power of willing, by means of which it re-acts on external objects. To these powers is super-added in the human species, that of reason, which may be regarded in physiology as one of the functions of the brain, because it requires in our present state of existence, the agency of that organ for its display. The connexion that has been observed between the development of the intellect and the perfection of the cerebral organ, has induced some celebrated philosophers to believe that the former is dependent on the latter, and that the phenomenon of mind is only a property of the material substances which compose the brain.

Without entering into any examination of the comparative merits of this question, I may be permitted to express my perfect conviction, that, if the investigation be conducted upon an anatomical and physiological basis, the materialists will fail in proving that the mental superiority of man is merely the result of the perfection displayed in his cerebral organization.

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* It is necessary to state, that there are beings on the extreme limit of the animal creation, which appear to have a sensibility scarcely different from that of vegetables; it is probable, however, that all animals are distinguished from plants by the capability of feeling the contact of any foreign body.

All the nervous functions are generally supposed to spring from one great property, which is named sensibility; by this word physiologists express: 1. The power which the nervous system possesses of receiving and transmitting certain impressions and producing corresponding changes in the sensorium.* 2. The power which the system enjoys of influencing the corporeal organs and in this manner of re-acting on external objects. In the first operation the impression passes from the circumference towards the centre of the system; in the second the influence extends in the opposite direction, or from the centre towards the circumference.

It has just been stated that all impressions are not necessarily attended with consciousness; for this reason sensibility is divided into two species. In one kind the impression *is not* communicated to the mind; thus we are not conscious of the impression of the blood on the heart: in the other kind, the impression *is* transmitted to the mind; for example we are aware of the contact of a foreign body with the finger. When an impression is thus perceived it constitutes a sensation or a perception.†

The influence of organic sensibility, by which word I wish to express all the actions of the nervous system of which we are not conscious, on the vital functions of digestion, circulation, respiration, secretion, and on the production of animal temperature, has, for a long time, engaged the attention of physiologists. The subject has been particularly investigated by Mr. Brodie, M. Le Gallois, and Dr. Philip. From the researches of these observers, we have obtained a variety of important information, but there are still many parts of this enquiry which remain involved in obscurity.*

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* It is, however, essential to notice that these two operations are not necessarily connected together, or in other words that it is no necessary part of this sensibility for the impressions to be perceived by the mind. Bostock, Elem. Sys. of Phy. vol. i. p. 244.

† Metaphysicians have made a distinction between a sensation and a perception; in physiology, however, the two terms may be considered as synonymous.

We learn from the experiments of Dr. Philip, that the nervous influence is essential to digestion. This process appears to be suspended in consequence of the secretion of the gastric fluids being stopped by the destruction of the nervous power of the stomach. The effect of these experiments on the secerning power of the internal surface of the stomach, lead to the supposition that the process of secretion in general is connected with the nervous influence, and cannot be performed without its intervention.† Although this deduction is probably correct, at least in the higher classes of animals, it must be acknowledged that the observations on which it is founded, are not sufficiently extensive to warrant us in deciding entirely in the affirmative.

The contractile power of the various structures which circulate the blood, is independent of the nervous system; but, as we have already seen, the heart and the blood-vessels are capable of being excited by the nervous power.‡

The influence of the par vagum upon the functions of the lungs has been known for a considerable time; it is, however, only lately that the precise effects resulting from the loss of the nervous power of the pulmonary organs, have been ascertained. The division of the par vagum, or the destruction of a considerable part of the spinal cord, causes an accumulation of frothy mucus in the bronchial tubes and air-cells, and a congestion of the blood-vessels of the lungs. The consequence of this obstruction is, that a smaller volume of air than natural is admitted, and that the blood contained in the pulmonary vessels cannot be brought in contact with the air, so as to undergo the necessary changes. In these cases the animal is destroyed by a process exactly similar to suffocation, except that it is less complete, and consequently less rapid in its progress.

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* I beg to refer the reader for many judicious observations on these disputed points, to the work of Dr. Bostock. The chapters which should be consulted, are those on the Circulation, vol. i. and on Respiration, Secretion, and Digestion, vol. ii.

† See p. 335.

‡ See p. 279.

One of the most important functions of the animal economy is that, by which the body is capable of resisting, to a certain extent, the changes of external temperature, and of preserving, more or less, an uniform degree of heat. It appears that the production of animal heat is connected with certain chemical combinations which occur in the process of respiration; but it has also been proved by the experiments of Mr. Brodie* and others, that the nervous power is essential to the evolution of caloric.†

The preceding observations are offered merely as a sketch of the important connexions that exist, between the nervous power and those organs which exercise functions essential to the support of life.

The actions of the nervous system, which are attended with consciousness, produce more striking effects than those depending upon organic sensibility. They consist, in the human species, of—1. Sensation. 2. Volition. 3. The intellectual faculties.

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* Phil. Trans. 1811, part i. p. 40.

† Sir E. Home found that the division of the nerves running to the horn of a deer, caused the temperature of it to fall 6° below that of the other horn; in some days afterwards, the divided nerve becoming united, the natural warmth of the part was restored. Philos. Trans. 1826.

Of Sensation.—When an impression made upon any organ of the body by a physical agent is transmitted to the brain, it produces a sensation; thus, when the vibrations of the atmosphere act on the nerve of hearing, we experience the sensation of sound. The sensations require to be divided into two classes, according as the cause that makes the impression, is external or internal. The external senses are five in number; vision, hearing, touch, taste, and smell. The number of the internal senses has not been satisfactorily determined. The sensations of hunger and thirst, and those which attend the actions of the muscles and of the genital organs, appear to belong to this class. Many physiologists believe that the power by which we are enabled to estimate the effects of temperature on our frame, should be regarded as a separate sense. Other writers, however, consider this power to be merely a modification of that function of the cutaneous organ, which is called tact.

In the exercise of the senses three conditions are necessary: 1. The impression of the physical agent upon the extremity of the appropriate nerve; 2. The transmission of that impression by the trunk of the nerve to the sensorium; 3. The perception of the impression by the mind. If any one of these conditions be wanting no sensation can be experienced.

The impression which is made upon an organ of sense is not perceived in the organ itself, but in the brain. It is true, indeed, if the feelings alone were relied on, we should conclude that the sensation is experienced in the organ, because we refer the perception to the part which receives the impression; thus the influence of light is felt in the eye, and the contact of a foreign body in the part of the skin which it touches. But experiment and observation inform us, that sensation resides in the brain; for if the communication be cut off between it and an organ of sense, no impression made upon that organ is perceived.*

Volition may be considered, in its general signification, as a modification of desire, resulting from painful or pleasurable impressions which have been perceived by the mind. But in a physiological sense, volition is used to express the stimulus by which the class of voluntary muscles is excited to action. In the exercise of this power, the influence, whatever it may be, is transmitted through a peculiar set of nerves from the centre towards the extremity of the nervous system.

Of the Intellectual faculties.—I shall not enter into the enumeration of the various phenomena which constitute the human intellect; because it would be impossible to do so without discussing the method according to which they should be arranged. Such an investigation would lead to details foreign to the object of this work, since almost every author who has considered this abstruse subject, has given a different account of the mental faculties.

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* Numerous experiments have been performed in order to ascertain the exact part of the brain on which impressions made on the organs of sense, exert their influence in order to excite perception. Although many of the results are extremely unsatisfactory and contradictory, yet it has been determined that if the cerebrum, the optic tubercles, and the cerebellum be removed, leaving the medulla oblongata entire to above the attachment of the fifth pair of nerves, the animal still retains its consciousness of all the sensations except that of sight. It also possesses volition. Thus it is briskly affected by sound, odours, and by sapid substances; it cries if a hair of its whisker be plucked, or if acid be dropped on its nose, and it endeavours with its paws to remove the irritating cause. Magendie et Desmoulins, Anat. de Sys. Ner. p. 560. A very interesting case is related by Mr. Lawrence of an infant which had no more of an encephalon than a bulb, which appeared to be the medulla oblongata, and with which all the nerves from the fifth to the ninth pair were connected. This child, which lived four days, moved briskly at first, took food, and discharged urine and fæces. The breathing and temperature were also natural. Med. and Chir. Trans. vol. v. p. 169. When the medulla is destroyed, the cerebrum, the cerebellum, and the spinal cord being left entire, the animal instantly loses all consciousness and power over the muscles. It is for these reasons that we are induced to place the seat of sensation and volition in the medulla oblongata.

The source of the mysterious power, which operates through the medium of the nervous system, is entirely unknown; we are even ignorant of the manner in which this power acts on the material organs, the brain and the nerves, that are essential to the manifestation of its phenomena. The deficiency in our information has not resulted from any want of inquiry, for this question has at all times commanded an intense interest amongst philosophers. I shall only notice in this place the most modern, and at the same time the most plausible of the numerous theories which have been invented to remove the difficulty.

It has been supposed by many eminent physiologists, amongst whom it will suffice to mention Cuvier, Abernethy, and W. Philip, that the power by which the nerves transmit impressions to and from the brain, is analogous to, or even identical with electricity. This hypothesis is strongly supported by the fact, that when a nerve is perfectly divided, its action may be imitated by galvanic electricity; thus, after the section of the par vagum, the secreting power of the lungs and stomach can be supported by galvanism. The evolution of heat from the blood, can also be accomplished by the same power;* and it is well known that muscular contraction is susceptible of being excited by the agency of galvanism. It is likewise worthy of remark, that when the par vagum is simply divided, the nervous power is still transmitted to the stomach; and even when the two ends are separated to the extent of a quarter of an inch, a part of the nervous power is conveyed from the upper to the lower portion of the nerve. These last mentioned phenomena are very similar to those produced by electricity; and tend, in a very forcible manner, to shew the identity of the nervous and galvanic powers. But in establishing a doctrine of such importance, further evidence is required, and therefore it will be prudent, in the present state of the question, to defer forming any definite conclusion.

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* See p. 39.

SECTION V.

DEVELOPMENT IN THE FŒTUS.

THE formation of the component parts of this system in the embryo, has been minutely investigated in the various classes of animals, and particularly in the human species. This comparative examination of the successive development of the brain and spinal cord, has elucidated the complicated organization of these bodies in man.

Although there is some difference of opinion as to the exact order in which the various parts make their appearance, it seems to be ascertained that the ganglions of the great sympathetic are formed before the spinal cord and brain; that the nerves on the sides of the trunk, of the head, and of the pelvis, exist independently of the spinal marrow, and indeed that they have acquired a considerable degree of development, whilst that body and the brain are still liquid and without form; that, next in order, the spinal cord is formed; and that lastly, the brain appears.

Anatomists, until very recently, supposed that the organs belonging to the nervous system in common with the other parts of the body, were developed from the centre towards the circumference; but from the researches of M. Serres, which have every appearance of accuracy, we learn that the spinal marrow and encephalon consist, in the first instance, of two lateral halves which are separated from each other, and which are afterwards gradually united on the median line, so as to constitute single organs. According to this principle of eccentric formation, the various nervous masses take their growth from the circumference towards the centre.

The first distinct traces of the cerebro-spinal axis cannot be perceived in the human embryo until about the fifth week after conception; at this period a membranous canal is observed in the spine, and which, in the head, is enlarged into a rounded pouch. In this tube and vesicle, which consist of pia mater, the rudiments of the two lateral columns of the spinal cord, and of certain parts of the brain, may be perceived in a strong light, and with the aid of a powerful lens.* A canal extends from the spinal membrane into the cerebral vesicle; and at a rather later period the two lateral columns incline from without inwards, and begin to unite on the median line.

In the third month the spinal cord is enlarged opposite the attachment of the limbs, and the rudiments of several parts of the cerebrum and of the cerebellum make their appearance. Some very important facts have been noticed in this month: the fibres of the spinal cord may be seen radiating upon the internal surface of the hemispheres; the latter are observed to curve from before backwards, and from without inwards, so as to form the lateral ventricles; they also unite in the median line, and thus give rise to the corpus callosum.

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* Tiedemann, Anat. du Cerveau, p. 14. Serres, Anat. Comp. du Cerveau, p. 84, *et seq.*

In the fourth month the median fissures of the spinal cord are perceptible. The various parts of the brain may at this time be perceived in a more advanced stage of their formation; the two lateral layers of the cerebellum unite in the median line, and thus the deep sulcus or furrow that previously existed between them is converted into the fourth ventricle; this cavity extends into the substance of the cerebellum, which is consequently hollow.

At the fifth month the anterior and the posterior roots of the spinal nerves are seen; the central canal may be inflated from the fourth ventricle. The cerebellum presents evident traces of a division into a central part or vermiform process, and lateral lobes; there are also four transverse furrows dividing the hemispheres into lobules. There are still no convolutions on the cerebrum, although there are deep lines indicating their situation.

During the sixth month the pyramidal, olivary, and restiform bodies are considerably enlarged; the latter penetrate into the cerebellum; the fibres of the corpora pyramidalia et olivaria traverse the annular protuberance, and then constitute the peduncles of the cerebrum, the fibres of which are prolonged towards the optic thalami, the striated bodies, the quadrigeminal tubercles, and ultimately, in a radiating manner, towards the cerebral hemispheres.

At the seventh month the lateral lobes of the cerebellum are proportionally more developed than the central part, which appears rather sunk or depressed. The transverse and ascending fibres of the annular protuberance are distinctly observed interlacing each other. The cerebral hemispheres, which now cover, and even extend beyond the cerebellum, present more evident rudiments of the convolutions; and the corpus callosum is seen to be composed of transverse fibres which unite the hemispheres to each other.

The various parts of the encephalon and spinal cord have acquired by the eighth month their external form, so that the remaining changes which they undergo till they attain their perfect organization, relate to increase in volume and density. The canal of the spinal cord is nearly filled with a soft grey substance, which appears to be deposited from the vessels of the pia mater that enter by the posterior furrow. The fibres of the bodies placed on the medulla oblongata are more distinctly observed passing to the respective organs with which they are connected. The layers of the cerebellum and the convolutions of the cerebrum become apparent; the hemispheres of both organs are developed and assume an arched convex figure; and, lastly, the internal parts are all more perfectly formed.

It is remarkable that during the whole period of the fœtal existence the spinal marrow appears gradually to ascend in the vertebral canal. When it is first examined, it reaches to the extremity of the os coccygis,* and thus resembles the caudal prolongation of animals;[*] subsequently, the termination is observed to be placed higher and higher, till at the time of birth it is situated opposite to the upper part of the third vertebra of the loins.

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* Serres, l. c. p. 102.

The increase of the nervous system, which is so rapid during the fœtal life, is checked after birth; the growth of the various parts, however, still proceeds, but more slowly. Many years elapse before the encephalon acquires its perfect formation, during which interval the organ is greatly augmented in volume and firmness. In old age there is a sensible diminution in the size of the nervous organs, probably depending on their greater density; this change is particularly observed in the brain, which, according to M. Magendie, loses a fifteenth part of its weight; it has also been stated that there is a corresponding decrease in the capacity of the cranium.[†]

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[*] The part called by anatomists *cauda equina*, which is caused by the ascent of the cord, becomes distinct about the sixth month.

[†] Tenon, Recherches sur le Crane Humain.

PART SECOND.

OF THE CEREBRO-SPINAL SYSTEM.

THE expression of *cerebro-spinal system*, was employed by M. Desmoulins to designate that part of the nervous system which consists of the brain and spinal cord. It appears to me that its meaning may be appropriately extended so as to include not only the encephalon and spinal marrow, but also the nerves which arise from those organs. With this signification, the term corresponds with "the nervous system of animal life," suggested by Bichat.

SECTION I.

OF THE NERVES.

THE nerves are whitish cords, which are made up of one or more threads, composed of the proper nervous matter enclosed within delicate processes or tubes of the membrane called neurilema; each nerve is connected either directly or indirectly, by one extremity to the centre of the system; and by the other to the skin, to the organs of the senses, or to the muscles. In classifying the nerves anatomists have been influenced rather by an attention to their numerical order, than to the essential properties by which they are distinguished. They have been very generally arranged since the time of Willis, as follows :—

I. Nerves of the Cerebrum.

1. The olfactory nerves.
2. The optic nerves.
3. The common motor nerves of the eyes.
4. The pathetic nerves of the eyes.
5. The trigeminal nerves.
6. The external motor nerves of the eyes.
7. The seventh pair, consisting of the hard and of the soft portions.
8. The par vagum and its accessory nerves.
9. The motor nerves of the tongue.
10. The sub-occipital nerves.

II. The nerves of the spinal cord.

III. The great sympathetic or intercostal nerves.

This arrangement is extremely defective, for it is not even correct according to the numerical principle on which it is founded. It was modified by Soemmering, who admitted forty-three pairs of nerves; he increased the number of cerebral nerves to twelve pairs, by dividing the seventh pair of Willis into the seventh or facial, and the eighth or auditory nerves; the eighth pair was in a similar manner divided into the ninth or glosso-pharyngeal, the tenth or nervus vagus, and the eleventh or accessory; the ninth pair in the old enumeration became the twelfth, according to Soemmering. The sub-occipital was properly considered as the first of the spinal nerves, the number of which was thus raised to thirty pairs. The forty-third pair consists of the great sympathetic nerves. This classification has been generally received by modern anatomists; but it is incorrect in one respect, viz. the enumeration of the nervus accessorius with the nerves of the brain.*

The objections that apply to both these qualifications are of a more important nature than those which merely relate to numerical errors. The principles on which they are founded are altogether trifling and unessential, and they are still more objectionable in a physiological point of view, because they include under the same denomination, nerves whose functions are totally dissimilar. A division like that of Willis or Soemmering can only be serviceable in oral demonstration, or in those anatomical works that are intended to supply the place of it; but in a treatise designed to illustrate the organization or the functions of the body, the arrangements of the various parts ought to be founded as strictly as it is possible, with a reference to their structure and use.

The nerves of the cerebro-spinal system may be divided into those with double and those with single roots or origins. The nerves of the first class are attached to the anterior and posterior columns of the spinal cord; they consist of thirty-one pairs, viz. the spinal nerves, (with the exception of the accessory) the sub-occipital, and the trifacial nerves of the head. These nerves have been proved by Mr. Bell to be subservient to the production of sensation and of voluntary motion. They constitute in the aggregate what that distinguished physiologist calls "the *symmetrical system of nerves*."* The nerves with single roots are generally connected with one function only, viz. with sensation or motion: those of the former class are the olfactory, the optic, and the auditory nerves: the motor nerves are the third, fourth, and sixth pairs belonging to the eye, and the sublingual or muscular nerves of the tongue.

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* The division of Bichat, who distinguished the cranial nerves into those of the cerebrum, of the annular protuberance, and of the medulla oblongata, is not founded on a correct anatomical basis. The same objection equally applies to the arrangement of Dr. Gordon.

There are certain other nerves which have also single roots, but whose offices have not been so satisfactorily determined; they consist of the hard portion of the seventh, the glosso-pharyngeal, the pneumo-gastric, and the spinal accessory. These nerves, together with the fourth pair, the sublingual, the phrenic, and the posterior thoracic,† are called by Mr. Bell the *superadded* or *respiratory*. The arguments and experiments by which this eminent physiologist supports his peculiar views, are extremely ingenious, and at the time when they were published, they appeared to be perfectly conclusive. The subsequent researches of Mr. Mayo have thrown, however, considerable doubts on the correctness of some parts of this celebrated theory.‡ Mr. Mayo concludes, that the portio dura of the seventh, and that portion of the fifth pair which does not enter the Gasserian ganglion, are the voluntary nerves of those parts of the face which receive their sentient nerves from the ganglionic portion of the fifth. He also supposes that several of the branches of the glosso-pharyngeal, the pneumo-gastric, and the spinal accessory, are nerves both of sensation and motion. It must be confessed that these conflicting statements shew the imperfection of our knowledge on this interesting part of the nervous system.

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* Exposition of the Nerves, p. 41.

† This is the inferior external respiratory of Mr. Bell's classification.

‡ See Anat. and Phy. Comment. part i. p. 107, and Outlines of Phy. p. 333.

As there is so much uncertainty concerning the nerves of respiration, it appears to be most correct to refer the cerebral and spinal nerves, according to their functions, to the three following classes: 1. Those of common sensation; 2. Of peculiar sensation; 3. Of voluntary motion.

The form of the nerves is in general cylindrical, but some of them are flat, and others of a triangular shape.

Although the nervous cords become successively smaller as they divide, yet the branches taken collectively are larger than the trunks from which they proceed; so that if the entire distribution of a nerve could be correctly represented, it would have the form of a cone, the point corresponding to the origin of the nerve, and the base to its termination. We learn from this fact that the quantity of nervous matter increases as the nerve passes from the brain;* this is an evident proof that the former is not a production of the latter, because in that case the reverse would be observed.

The disposition of the nerves presents three points for consideration: 1. Their origin; 2. Their course; 3. Their termination.

ORIGIN OF THE NERVES.

We understand by the origin of a nerve the extremity which is attached to the encephalon, or spinal cord. Some anatomists consider the origin to be placed exactly at the point where the nerve completely leaves the external surface of the above organs; thus they say that the origin of the optic nerves is in the commissure of the tractus optici, and not in any of those parts with which these tracts are connected behind. It is, however, necessary to trace the nervous roots beyond the mere surface, so that their real connexions may be understood; and in order to accomplish this object the parts must be hardened by the continued action of alcohol. When a nerve is examined in this manner, its fibres may be followed as far as the grey substance of the medulla oblongata or spinalis. It is a very common opinion that the nerves arise from the fibrous substance, and that they are, in fact, simply prolongations of it; but it is now ascertained that the nerves always communicate, more or less, with the grey matter. This connexion, which appears to have been noticed by Vicq-d'Azyr,* has been particularly insisted upon by Gall, to whom we are indebted for a knowledge of its importance.

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* This remark is made by Dr. Monro, who considers, and without doubt correctly, that the pia mater of the nerves, or the neurilema, supplies the additional nervous matter.

In order to render the description of the origin of the nerves intelligible, it is essential to offer a few observations on the structure of the spinal cord. The reader will recollect that in tracing the development of this part in the fœtus, it was stated that it consisted, in the first instance, of two lateral columns, which subsequently coalesced on the median line. In the adult there still remains an indication of the primitive condition, the nervous mass of the spine being composed of two similar and lateral halves, which are separated to a certain depth by an abdominal and a dorsal furrow. These cords are united in the interior by some communicating nervous substance, which is named their commissure.

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* Traité d'Anatomie, p. 508. An opposite opinion is expressed by Desmoulins.

Each lateral column is marked by an anterior and posterior furrow, which receive the roots of the spinal nerves; there is also a third and shallow groove found on either side, between the posterior lateral and posterior median furrows. In this manner it appears, as Mr. Bell some years since surmised, that each lateral half of the spinal mass is divided into three distinct longitudinal cords. The spinal cord is enlarged opposite to the origin of each nerve, so that it exhibits a nodulated appearance.*

Several writers contend, that all the nerves of the cerebro-spinal system may be traced to the spinal cord, and to the medulla oblongata; but from this statement the first, and perhaps the second pairs,† ought to be excluded, because they are certainly connected with the cerebrum. With respect to the other cranial nerves, it is well known that, as high as the sixth pair or the motores externi, they are immediately attached to the medulla oblongata, and the others may be shewn to be connected either directly or indirectly with that important structure. Thus the fifth pair, which appears to arise from the pons varolii, only passes through that body, the real origin being placed between the corpora olivaria and restiformia;[*] the fourth pair proceeds from the valvula of Vieussens, which is continuous with the corpora olivaria; and the third pair is connected with the interior of the crura cerebri, which are merely the prolongations of the pyramidal and olivary bodies.

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* Gall considers the spinal cord to be composed of a series of ganglions, which are united to each other by nervous cords; in the mammalia, these nodules are so close together, that they form a cord of nearly an equal size in its whole length. Recherches sur le Système Nerveux, p. 89. A similar opinion is supported by Mr. Mayo, who compares the several segments from which the spinal nerves proceed, to the ganglions observed in the invertebrated animals.

† The optic nerves are attached to the corpora quadrigemina and geniculata, and they are also connected with the crura cerebri; in this manner they indirectly communicate with the bodies of the medulla oblongata.

Each nerve of the spinal cord has two roots, an anterior and a posterior, which being placed in the lateral furrows, are separated from each other by the denticulated ligament. The filaments which compose the anterior root, are more irregular in their disposition than those of the posterior root; they are also smaller and more numerous. The posterior fibres are arranged in a regular series, and pass out more abruptly from the spinal cord than the anterior fasciculi. There is a difference of opinion as to the respective volume of these two roots; it is stated by Gall, that the posterior origin is the larger one; but according to Desmoulins, this only applies to the nerves of the brachial or axillary plexus; in the dorsal nerves the two roots are nearly equal, while in those of the loins, the anterior roots predominate in size over the posterior.[†] The fibres of the two roots may be followed into the substance of the spinal cord, where they are observed to be partly continuous with the fibrous matter of the corresponding column, and partly with the lunated extremities of the grey matter. Each root perforates the theca vertebralis separately; a ganglion is then formed on the posterior fasciculus, and immediately afterwards the two roots unite so as to form one nerve. The fact of the anterior root being entirely unconnected with the ganglion, was distinctly noticed by Monro.

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[*] Cloquet, Anatomy, p. 453. See the Plate in Mayo's Outline of Phy. p. 342.

[†] Anat. des Sys. Ner. p. 493. The nerves of sensation are considerably larger than those of motion; thus the posterior or sentient filaments of the brachial nerves are at least five times larger than the anterior or motor filaments. Ibid. p. 775.

It has been supposed by some anatomists that there is a decussation between the roots of the nerves; inspection shews, however, that this intercrossing of the fibres does not exist, and also that there is not any communication across the median line, between the nerves of the two sides of the body. We must except from this statement the optic nerves, which, according to the best authorities, partially decussate in their commissure. The pathetic ought also to be distinguished, because they are frequently united at their origin by a transverse band, and likewise the auditory, which are occasionally connected by some white striæ in the floor of the fourth ventricle.

COURSE AND TERMINATION.

The nerves take their course in a direction which corresponds, more or less, with the long axis of the body; but near their origin they pass differently; thus the spinal nerves run outwards nearly at a right angle with the trunk. The nerves which are called the respiratory, are more irregular in their disposition, and in consequence of their direction, they often cross the preceding nerves, so as to produce a very complex appearance in the face, throat, and neck. The nervous trunks, as they pass towards their destination, furnish branches which commonly separate at an acute angle; they also form numerous communications with nerves of the same and of different classes.

The mode in which the nerves terminate is not known, with the exception of the optic and the auditory nerves, each of which expands into a delicate and transparent pulp, that becomes opake after death. When the nervous fibres are traced towards the different organs, it is observed, that the neurilema either becomes extremely thin, or is altogether lost, so that there is little else than the nervous matter, which, being very soft, cannot be followed to its ultimate termination. It is impossible to ascertain the nature of the connexion that exists between the nerves and the parts they supply; all that can be seen by a careful inspection is, that the fibres, just before they appear to end, are generally enlarged, and rather flattened; they then suddenly escape observation, while their size is still considerable, being about twelve times larger than the muscular filaments.

SECTION II.

ORGANIZATION.

EACH nerve is composed of delicate filaments, or fibrillæ, which seem to vary in thickness, from the size of a hair to that of the finest fibre of silk; these filaments, each of which is enclosed in a proper cellular sheath, or neurilema, are collected into fasciculi, and, in their course, they divide and subdivide, and are generally thought to communicate freely with each other.*

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* See p. 479.

The fasciculi, like the fibrils, are of various sizes; some are an eighth of an inch in thickness, and others scarcely more than a hundredth part of an inch. The greater number of the nerves consist of several of these bundles, but some among them only possess a single fasciculus.

The neurilema forms an assemblage of small canals, which may be rendered apparent by injecting them with quicksilver, after the nervous matter which they contain, has been dissolved in a diluted alkali. These sheaths are connected together by a loose cellular tissue, which may be seen with the naked eye between the large fasciculi: in some nerves a small quantity of fat is accumulated.

The proper nervous matter may be obtained separately from the neurilema, by the action of nitric or muriatic acid; it is generally supposed to consist of the fibrous or white substance of the brain. It was however stated by Monro, that the nerves, with the exception of the optic and auditory, are of a browner colour than the medullary substance; he supposed that the neurilema furnished a quantity of cineritious matter.

The arteries of the nerves are large and numerous, and may be seen in many of the nerves penetrating between their fibres. Each vessel subdivides into two branches, one of which observes the same course as the nervous trunk; the other passes in a retrograde direction. When the arteries have been successfully injected, the nerves, in consequence of their great number, appear red; they ramify on the neurilema of the filaments, but their mode of connexion with the nervous matter is not known: the veins are numerous, and may be often seen filled with blood. The absorbent vessels can only be traced in the large nerves, and some anatomists altogether deny their existence.

The density of the nerves is liable to considerable variation; this circumstance depends on the strength of the neurilema, which varies according to the degree of exposure to which the nerve is subjected. Thus in the limbs the sheaths are thick and strong; the optic nerve is also provided with a dense envelope, by means of which the rapid and numerous movements of the eyeball are effected without injury to its texture; on the contrary, in the auditory, and especially the olfactory nerves, the neurilema is extremely delicate.

The nerves are but little elastic. When they are irritated in a living animal, no movement or vibration can be perceived in any part of them.

The functions of the nerves are principally, if not entirely, confined to receiving and transmitting impressions to and from the brain, and also from one part of the system to another, in which process the brain is not necessarily concerned. The volitions of the mind are conducted with a wonderful and incalculable rapidity from the encephalon to the muscles; and, in an opposite direction, the impressions of external bodies are conveyed to the seat of perception. That the nerves are the agents by which the influence is transmitted in both these instances, is evident from the fact, that if they are tied or divided, the muscles cannot be excited by the will, nor can the sensorium be impressed by external objects.

Anatomists, from the time of Galen, have endeavoured to determine if there be not peculiar nerves or fibres destined for sensation, and others for motion. It was long since ascertained that some nerves were entirely connected with sensation, as the first, the second, and the soft portion of the seventh pairs; and that others, as the third, the fourth, the sixth, and the ninth pairs, were motor nerves; but the characters of the compound nerves, the trigeminal and spinal, were not understood.

To Mr. Bell, indisputably, belongs the honor of being the first anatomist, who by direct experiment proved the difference in the functions of the anterior and the posterior roots of the spinal nerves. Many years since Mr. Bell published the following important observations: "I found that I could cut across the posterior fasciculus of nerves, which took its origin from the posterior portion of the spinal marrow, without convulsing the muscles of the back; but that on *touching the anterior fasciculus with the point of the knife the muscles of the back were immediately convulsed.*" It is apparent, from this paragraph, that Mr. Bell had made the grand discovery with respect to the distinct offices of the two roots of the spinal nerves; and also that he had ascertained that the anterior fasciculus was alone connected with the production of motion. Although no one can more highly appreciate than I do the excellent motive which actuated this distinguished physiologist, yet it is much to be regretted that he was deterred by feelings of humanity from prosecuting at that time his enquiries on this interesting subject.

It will I think be allowed by every candid and unbiassed observer that a few repetitions of the above experiments would in all probability have led to this conclusion: that, as the spinal nerve was known to be subservient to sensation and motion, and as the anterior root had been proved to be connected with the latter function, the posterior root must be connected with sensation. In this stage of the inquiry M. Magendie performed his experiments, and proved what Mr. Bell's previous investigations almost implied, that the anterior fasciculi are nerves of motion, and the posterior nerves of sensation.*

The power of the nerves, which appears to be restricted to that of conductors, is shewn by Dr. Philip to be different from, and in a certain degree independent of, that of the brain. The independence of the nervous power is illustrated by the experiments of Sir Gilbert Blane, who found, after the head was removed, or the spinal cord divided in young kittens, that the hind legs shrunk from the touch of a hot wire applied to the hind paws. In this instance, the impression made on the nerves of the skin must have been transmitted to the nerves of the muscles, which were, in consequence, excited to contract. In connexion with this subject I may notice an interesting observation of Mr. Mayo: he has remarked that nerves of motion take their rise from the same region with those sentient nerves which transmit the im-

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* The comparative merits of Mr. Bell's and M. Magendie's discoveries have been frequently discussed; but, as there still exists some difference of opinion respecting them, I am induced to state a few facts which bear upon the point at issue. It appears that the experiment of dividing the portio dura in the horse was performed near Paris in the presence of M. Magendie, and he was informed it was the same experiment that Mr. Bell had already performed. *The experiments of Mr. Bell on the spinal nerves, and his reasoning with respect to their functions, were also explained to M. Magendie, and the publication containing an account of them was given to him.* It is necessary to bear in mind that *all this took place some time before M. Magendie performed his experiment* of dividing the roots of the spinal nerves, and which experiments, he says, he made without at all expecting any particular results from them. These circumstances were mentioned by Mr. Bell in his lectures delivered at the College of Surgeons in the summer of 1828. I took a few notes at the time, and from them this statement is copied.

pressions, by which their action is usually regulated. This principle is immediately apparent in the spinal nerves, the anterior or the motor portion of which proceeds from the same segment with the posterior or the sentient portion; and a similar arrangement may also be traced in the nerves of the encephalon.

PART THIRD.

OF THE GANGLIONS, AND OF THE GREAT SYMPATHETIC NERVE.

In concluding this chapter, I shall consider those parts of the nervous system whose operations are not usually attended with consciousness, and which are principally subservient to the vegetative or organic functions. They consist of the ganglions and nerves of the great sympathetic.

Section I.

OF THE GANGLIONS.

The nervous ganglions are round or oval bodies, which are situated along the course of the nerves; it is remarkable, however, that they are only met with in the trunk of the body, the limbs being entirely destitute of them.

The word *ganglion* was employed by the ancient authors to designate certain hard tumours, which were placed on the tendons, or in their neighbourhood. Many anatomists, and especially Vesalius, attribute to Galen the honour of discovering and naming the ganglions of the nerves; but Fallopius is more generally regarded as the first anatomist who distinguished these peculiar bodies. In the present day the term ganglion has been used with a more extended meaning by several writers, who have described by this name the masses of grey substance which are met with in the different parts of the spinal cord and brain. Thus they speak of the ganglion of the cerebellum (corpus dentatum), the inferior and superior ganglions of the cerebrum (the optic thalami and the striated bodies). The expression is, however, generally restricted to the nodules that are placed on the nerves, and it is according to this acceptation that we shall employ it in the following pages.

In order to prevent repetition I have deferred the description of the spinal ganglia to this section; but it is necessary to bear in mind, that, although their structure is investigated with those of the sympathetic, their functions are apparently altogether dissimilar.

The ganglions of the human body, which are liable to some variation as to their number, usually consist of the following: thirty on each side of the body, placed on the posterior roots of the spinal nerves; on either side of the head there are the gasserian ganglion, situated on the large origin of the fifth pair, the ophthalmic ganglion, and the spheno-palatine ganglion of Meckel. The naso-palatine ganglion of Cloquet is placed in the anterior palatine foramen; a slight enlargement is occasionally seen on the chorda tympani, which is called the sub-maxillary ganglion; a gangliform swelling is also observed on the commencement of the pneumo-gastric, and another on the glosso-pharyngeal nerves; and a small body is said to be sometimes placed in the cavernous sinus, the cavernous ganglion.

The great sympathetic has generally the following ganglia: three cervical, twelve dorsal, five lumbar, and three or four sacral; these nodules are situated on either side of the median plane of the body, on what is considered as the trunk of the sympathetic. There are also the cardiac, the two semilunar, and several cœliac ganglia, placed on the branches of the nerve, in the neighbourhood of the median line.

The ganglions have been divided into classes, according to their connexions and uses. Scarpa and Meckel divide them into simple and compound; the former being placed on the spinal nerves, and the latter on the great sympathetic. Weber distinguishes them into ganglions of reinforcement, such as the spinal, and some of those placed on the cranial nerves; and into ganglions of origin, to which class those of the sympathetic, and also the ophthalmic and the spheno-palatine, belong. They have likewise been divided into the cerebral, the spinal, and the sympathetic. The arrangement suggested by Scarpa is the most judicious, because it is founded upon the differences which these bodies present in their structure and in their functions.

The *simple ganglions*, which comprehend those of the spinal and trigeminal nerves, are very constant in their situation and in their form. Each of these knots has two fasciculi of nerves connected with it; one extends between the ganglion and the posterior column of the spinal cord, and the other from the ganglion to the anterior root of the nerve, with which it unites. They are enveloped in a dense external capsule, which is connected with the dura mater, and, by a more delicate membrane, which is said to be a continuation of the pia mater.

The *compound ganglions* consist of the nodules situated on the trunk and branches of the great sympathetic, and of the ophthalmic, the spheno-palatine, and the naso-palatine ganglia. The form, the number, and the situation of these bodies, are liable to considerable variation; but the irregularity does not appear to be so great as Bichat represented. They resemble each other by the complex arrangement of their nervous filaments, which are generally attached to several points of their surface, and not merely, as in the simple ganglions, to their two extremities. The external covering, which is not so dense as that of the first species, results from the condensation of the surrounding cellular substance.

The form of these bodies is usually oval or circular; but they are frequently observed to be considerably elongated, and sometimes triangular.

The structure of the ganglions has been minutely examined by several anatomists; but it will be only necessary to notice the observations of Monro* and Scarpa,† which are the most accurate and satisfactory. According to the first of these writers, however different from each other the ganglia may appear in form and situation, their general structure is alike in all of them. They are composed of two substances, which are commonly regarded as being analogous to the fibrous and grey substances of the brain. The first, or the medullary portion, consists of numerous threads, which are evidently the continuation of the nervous fibres that are attached to the ganglion, and which may be distinguished in its interior by their form and colour. The surface of these fibres is said to be less distinct than in the nerves; this is either owing to the loss of their neurilema, which is supposed to be united to the dense envelope of the ganglion; or, as is more probable, to the circumstance of this membrane becoming much more delicate, and consequently difficult to detect.

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* Obs. on Nerv. Sys.

† De Nervorum Gangliis.

The second, or the peculiar substance of the ganglion, is of a pulpy consistency, and of a reddish grey colour; it surrounds and incrusts the nervous filaments, and thus establishes a most intimate connexion with them. This pulpy matter is stated by Scarpa to be composed of an oily substance, and even of fat in very corpulent subjects; and in this opinion Meckel seems to concur.

The arrangement of the fibres and pulpy matter in the interior of these bodies, is not satisfactorily understood. We are informed by Monro, that the nervous filaments are not interrupted within the ganglion, but they may be traced in every part of it; these threads, however, are very intimately connected together, so that the nerves which issue from a ganglion, are composed of filaments proceeding from all the nerves that enter it.

The texture of the spinal ganglia is comparatively simple; the fasciculi of the posterior root on entering one of these nodules, divide into several white filaments, which, although they subdivide and reunite between themselves, pass in one direction, namely, outwards. The fibres having emerged from the ganglion, unite almost immediately with the anterior root, in order to form the common trunk of the spinal nerve. This trunk communicates with the neighbouring ganglion of the great sympathetic, usually by two branches, and thus establishes an intimate connexion between the two systems of nerves. Towards the conclusion of the last century, there was a discussion as to what exact part of the spinal nerve sent off this communicating branch to the sympathetic. It has been determined, by careful dissection, that the connexion exists between the common trunk of the nerve and the ganglion.

The compound ganglions present a more intricate texture in their interior; the filaments of the nerves are followed with more difficulty, on account of their interlacement with each other, and their intimate connexion with the peculiar reddish grey substance, met with in these bodies. The nerves passing from the ganglions of this class, are distinguished by their number, and by their complex disposition; in some instances they have the appearance of radii proceeding from a centre, an arrangement strikingly evinced in the formation of the solar plexus.

The nerves passing out of a ganglion are usually rather larger than those which enter it. This circumstance, joined to some other considerations, has given rise to the opinion, that nervous filaments originate in the grey matter of the ganglions. Scarpa, however, conceives that the nerves, in passing through a ganglion, are merely modified in their arrangement; and that they are intimately united with each other. I am inclined to adopt the former theory; because it is probable that the grey substance performs here, as it does in the other parts of the system, a more important office than simply connecting together the white fibres; and also, because the character of the nerves issuing from the ganglions, is different from that of the nerves which enter.

The arteries of the ganglionic system, which are numerous, ramify on the membranous envelope, and afterwards penetrate into the pulpy and fibrous substances, where, after freely ramifying, they terminate. The veins correspond in their number and disposition with the arteries. The lymphatic vessels cannot be distinguished in the ganglions.

SECTION II.

OF THE GREAT SYMPATHETIC NERVE.

THIS nerve, which is called by many authors the *intercostal* or *trisplanchnic*, is composed of the compound ganglions described in the preceding pages, and of various filaments extended between them in such a manner, as to produce a continuous cord, which reaches from the head to the termination of the vertebral column. The uninterrupted course of this ganglionic cord, has caused the majority of anatomists to regard it in the same light with the other nerves of the body; having like them, an origin in its cephalic, and a termination in its pelvic extremity.

We are indebted to M. Le Gallois and Dr. Philip, for more correct information upon this subject. These physiologists place the origin of the great sympathetic in the spinal cord, from every part of which it receives communicating branches.* The ganglionic system is also intimately connected with the brain by means of several filaments which pass from the sympathetic to the cranial nerves. The par vagum is the principal medium by which this communication is established, in consequence of its frequent union with the sympathetic in the neck, in the chest, and especially in the abdomen. It may be advisable to notice, that the unions of the first cervical ganglion with the spheno-palatine ganglion, by means of the vidian nerve, and with the sixth pair, by the branches which ascend into the cavernous sinus, have often been erroneously considered as the origin of the great sympathetic nerve.

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* Le Gallois sur le Principe de la Vie, p. 150. Philip, l. c. chap. 9, p. 159. It is necessary to state, that the ganglial system has been known to exist without the spinal cord or brain, in acephalous monsters.

The irregularity in what is called the trunk of the sympathetic and in its branches, is very great, and was particularly noticed by Bichat. The filament which forms the connexion between the different nodules, is occasionally deficient, and in this manner causes an interruption in the nerve, but without affecting its functions. In some instances one or more of the ganglia are absent, while at other times their number exceeds the ordinary average. The branches present many deviations from the usual arrangement, in their origin and distribution, which are thus strongly contrasted with the regularity and symmetry of the cerebro-spinal system.

The ganglionic nerves are distinguished from those of the spinal cord, by their redder colour, and by their pulpy structure. According to Scarpa, they may be divided into filaments; but I agree with Beclard, in thinking that it is impossible to trace these threads, particularly in the nerves of the solar plexus. The neurilema is thin, and so intimately united with the nervous pulp, that it is distinguished with difficulty.

The distribution of the ganglionic system of nerves is very extensive; indeed, according to Dr. Philip, it is equal to that of the cerebro-spinal nerves. The branches of the sympathetic supply the organs of digestion, of circulation, and secretion, and in part those of respiration; the principal organs of generation also receive their nerves from the same source. A few branches from the sympathetic are furnished to the muscles of the neck, thorax, and abdomen.

SECTION III.

FUNCTIONS OF THE GANGLIONIC SYSTEM.*

THERE is no part of physiology which is more obscure than that which relates to the uses of the great sympathetic. The deficiency of all positive information on this subject, has given rise to a great number of theories, which have from time to time occupied the attention of the scientific world. I shall, however, merely notice a few of those which have enjoyed the greatest celebrity.

Vieussens and Lancisci imagined that the ganglions possessed a muscular structure; and the latter thought that by their contraction they accelerated the flow of the nervous spirits. According to the hypothesis of Winslow, which had so much influence on the opinions of succeeding writers, the ganglia are independent centres, giving new power to their nerves, and in fact constituting so many small brains. Johnstone supposed that these bodies are the instruments by which the motions of the involuntary muscles, as the heart and the intestines, are rendered uniformly independent of the will. An opinion in many respects similar to the theories of Winslow and Johnstone, was supported with great ability by Bichat. This celebrated anatomist contended that each ganglion ought to be regarded as an independent centre, furnishing or receiving its proper nerves, and connected by anastomosing filaments, with the surrounding ganglia. He conceived that the great sympathetic nerve was composed of a series of these nodules, and that it governed the organs of the vegetative functions.

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* The observations contained in this section do not apply to the spinal ganglions.

Many physiologists, as Meckel, Scarpa, and Le Gallois, suppose that the use of the ganglia is to divide, to mix together, and to re-unite the nervous filaments that they receive. Dr. Philip concludes that they constitute a secondary centre of nervous power; and as they receive the influence of every part of the brain and spinal marrow, they bestow on the thoracic and abdominal viscera, on the vessels and all secreting surfaces, the combined influence of those organs.

Notwithstanding the unwearied patience with which these inquiries have been pursued by so many eminent men, the functions of the sympathetic remain still undetermined. The experiments of Dr. Philip seem to establish the conclusion mentioned above; but there are doubtless other operations effected by means of the ganglions, which have in all probability, an important influence on the vital processes of digestion, respiration, circulation, secretion, and generation.

In concluding these observations, I shall allude to an error which having received support from very high authorities, has had an injurious effect upon this and other inquiries concerning the functions of the nervous system. I allude to the doctrine according to which the ganglia are provided to cut off the parts they supply with nerves from all connexion with the brain. The fallacy of this opinion has been demonstrated by Dr. Philip, as far as the ganglions of the great sympathetic are concerned; and in an equally satisfactory manner by Mr. Bell, with respect to the ganglions of spinal nerves.

THE END.

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